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Topics of the Month

Nuclear engineering in France

ALTHOUGH the French atomic energy project is small compared with those of Britain and the U.S. it is technically interesting because from the outset it has been concentrated on the production of useful industrial power. About a year ago France's second atomic pile, a medium powered reactor, began operation at Saclay, west of Paris. In a recent issue of our associate journal, *Atomics*, details are given of the engineering of this reactor. The uranium used is in the form of 136 rods, each 1.1 in. in diameter and 7 ft. long, arranged in the form of a triangular lattice with rod spacing of 5.93 in. These rods are immersed in an aluminium tank approximately 8 ft. in height and rather more than 6 ft. in diameter, which is partly filled with heavy water. The tank is surrounded on sides and bottom by a graphite reflector 3 ft. thick; there is no reflector above the tank, owing to the interference it would cause with the handling of the uranium rods. Outside the reflector is a cast-iron thermal shield approximately 8 in. in thickness, and the whole assembly is encased in a concrete shield a little over 7 ft. in thickness. The pile is controlled by means of reactivity changes induced by cadmium plates moving between the tank and the reflector. If a greater degree of control is required, two shut-off rods of cadmium can be lowered into the tank.

The most interesting feature of the pile is the solution of the problems involved in pressure-gas cooling the uranium. The fuel elements consist essentially of four concentric aluminium cylinders, the innermost of which is the protective sheath surrounding the uranium bar. The coolant, nitrogen under 10 atmospheres pressure, enters at an inlet union at the top of the fuel element, and flows down the space between the two outer cylinders. It then passes back again, at high velocity, over the surface of the inner cylinder which is itself the 'can,' in direct thermal contact with the uranium. The space between the second and third cylinders forms an insulating layer of gas, which prevents heat being exchanged between the upward and downward currents of nitrogen. This design ensures that the aluminium surfaces in contact with the heavy water are adequately cooled. It also provides a neat solution to the problem of making the coolant connections to the fuel elements; since both inlet and outlet are at the same end, there is no problem of having to take the gas connections through a water-tight seal in the bottom of the tank.

After leaving the reacting core of the pile, the nitrogen passes to a heat exchanger, where it is cooled before being recirculated. An auxiliary ventilation system ensures that any slight leaks from the coolant circuit are led away and discharged harmlessly into the atmosphere through a chimney.

The pile was first operated at low power on October 27, 1952; since then the operating power has been slowly increased towards the designed figure of a little over 1 mW. At this rate the pile will produce about 1 g. of plutonium per day, an amount which although small, will nevertheless make possible a large number of physical and chemical studies of this important nuclear fuel.

A key to university research

A LOT of important research done in our universities is never published and to this extent it loses a good deal of its value. We refer to research done in preparation for theses for higher degrees. In Britain these theses exist usually only in typescript and once accepted they go completely unrecorded. It is a great pity that this work, often carried out with expensive apparatus and other facilities and under the direction of very experienced people, should thus be forgotten. In America, some universities and institutions prepare abstracts of theses which give at once an index of such papers and some idea of what they contain. In this issue of CHEMICAL & PROCESS ENGINEERING, for instance, we reprint from the latest 'Abstracts of Theses' issued by the Massachusetts Institute of Technology, ten abstracts of chemical engineering interest.

Now, a move to record the hundreds of British higher degree theses has been made by the Aslib organisation who have published the first volume of 'Index to Theses accepted for Higher Degrees in the Universities of Great Britain and Ireland.' Some 2,200 theses are listed, each entry giving the title, the author's name and university, and a note indicating availability to the public. The index costs 25s. net and is available from Aslib, 4 Palace Gate, W.8. It is intended to publish indexes annually.

Colliery methane fuels a town

THE extraction of methane from coal mines is an excellent example of how to remove a hazard and simultaneously turn it to advantage. The systematic tapping of coal measures to extract methane at one stroke makes the mine safer and provides a valuable fuel. In Britain the National Coal Board is now experimenting with methane drainage at 16 collieries in different parts of the country and is planning to try it at seven more. At Haigh Colliery, Whitehaven, Cumberland, work has reached the stage where the methane extracted from the mine is being piped to the local gasworks for processing and distribution as town supply. During the past 11 months about 500 cu. ft. min. of pure methane has been extracted from Haigh Colliery. Some of it has been used to heat the colliery boilers and this alone has saved about 7,500 tons of coal. At Point of Air Colliery, North Wales, experiments are reaching a similar stage and soon towns in the vicinity will be supplied with methane from the gasworks.

Methane as extracted from collieries is not suitable for burning in appliances designed to use ordinary coal gas and before it can be distributed it has to be processed. At Whitehaven the method of catalytic reforming is used in which part of the methane is mixed with steam and passed over a hot nickel catalyst. The reformed product is mixed with raw methane to make a gas blend identical with the usual supply in behaviour and heating value. The retorts at the Whitehaven gasworks are being used as catalytic chambers until a properly designed furnace has been built.

Although employment as a fuel is the obvious and usually the most convenient way of using methane, there are other possibilities. For the chemical industry the most interesting is that of using it as a raw material for the synthesis of acetylene or for the production of chlorinated methanes. To be technically successful, however, such processes would require large tonnages of methane which would not likely to be available from single collieries. However, if it proved possible to group a number of pits for methane drainage the way might be opened for the establishment of a chemical industry to utilise the supply. Even if this possibility is never realised, it is good news that methane drainage has now become a practical operation in British coal mines. Even on safety grounds alone it is a most commendable achievement.

Tracking atmospheric fluoride

HOW to detect and record the presence of hydrogen fluoride gas (HF) in the air in the vicinity of certain industrial plants has been a problem recently tackled by the Stanford Research Institute of America. Such concentrations are sometimes great enough to cause damage to vegetable and animal life, though only in the parts-per-billion range, say 5 or 10 thousandths of a microgram of HF in a litre of atmosphere.

It was felt by the Institute that there was a need for some sensitive analytical instrument which would give continuous indication of the level of fluoride concentration and which would operate for days without attention.

A search through literature on the subject revealed that in 1949 a short article in *Analytica Chimica Acta*, published in Amsterdam, described a simple sensitive method for detecting traces of HF gas. By this method a piece of filter paper is dipped into a chloroform solution of a fluorescent metal salt of 8-hydroxyquinoline (oxine) and the solvent is evaporated. Remaining behind in the filter paper the metal oxinate, under black light illumination, fluoresces brilliantly. This fluorescence is diminished or 'quenched' by contact with traces of HF.

Based on this procedure, the Institute's analytical chemists produced an instrument incorporating a 350-ft. roll of 35-mm. filter tape impregnated by a mechanical process. An elaborate system was evolved for generating synthetic atmospheres containing exact concentrations of HF which, when drawn past the moving tape, acted on the impregnant. Minute variations in fluorescence could then be measured photo-electrically, the results being graphed on a continuous recorder.

The sensitivity of the instrument is in the desired range of parts-per-billion of HF and it is thought that, although there are still some problems to work out, it will meet the requirements. A field instrument is to be built and tried under actual operating conditions.

Research in this field has now been turned to developing the instrument so that it can be used for detecting particles of fluoride in the atmosphere in addition to gases. Such particles as calcium fluoride or iron fluoride may be emitted from industrial chimney stacks and be carried to spots many miles away.

Plans for this further research include the conversion of fluoride particles into HF through reaction with the water vapour in the atmosphere. Preliminary tests have indicated that such conversion might be effected simply by passing the sampled air stream through a hot zone. If such a pyrohydrolysis reaction could be incorporated the total atmospheric fluoride might be determined.

New processes for producing coke from non-coking coals

AMONG the problems created by the dwindling of the world's coal reserves is the shortage of coal suitable for processing to metallurgical coke. In Britain, at least, the problem is not a new one. It was predicted some years ago, in *The Efficient Use of Fuel* (H.M.S.O.), that the U.K. would soon face a real shortage of first quality coking coals. Earlier this year H. D. Greenwood, M.I.Mech.E., at a joint meeting of the Institute of Fuel and the Coke Oven Managers' Association, said that the shortage might lead to a change in the techniques and plant used by the coking industry (see CHEMICAL & PROCESS ENGINEERING, March 1953).

But the problem is not confined to the U.K., for the development of coking processes for non-coking coals is the object of a Working Party recently set up by the O.E.E.C. The study of such processes has received relatively little attention so far, as industrial trials of this type of process call for costly installations. Now, however, the O.E.E.C.'s Working Party has drawn up a list of the carbonisation and semi-carbonisation processes other than the standard coke-oven method. This list includes current processes, new processes which have reached the industrial stage and new processes not yet industrially tried out. From the latter group the working party has selected three processes which seem likely to prove applicable to a wide range of different types of coal. The creation of international working parties to study these processes is now under consideration.

The three processes are the U.S. National Fuel Corporation's process, the Baum and Baum-Panindco process, first tried out in Germany, and an electrical coking process originating in Norway. The first two are claimed to be applicable to a very wide range of types of coal, from anthracite to bituminous. As both of them belong to private concerns at present, however, the Working Party will have to negotiate with the owners for setting up a pilot plant in Europe. The Baum and Baum-Panindco process, in its original form as the Baum process, was actually tried out on an industrial scale, but the experiment was interrupted by World War 2 before any technical or economic conclusions could be drawn either for or against.

With Spitzberger coal, and with bituminous coal from the Ruhr, the Norwegian process seems to have given good results as regards the fuel produced, but the electricity cost involved seems prohibitive for most of the countries concerned.

A report summarising the technical details of these and other new coking processes has been published by the O.E.E.C. and may be obtained from the Secretariat of the Productivity and Applied Research Committee, 2 Rue André-Pascal, Paris XVI.

Alumina from anorthosite

REPRESENTING a major phase of the U.S. Bureau of Mines programme to develop industrial processes for producing aluminium from domestic raw materials, an experimental production of this metal from anorthosite is being tried out at Laramie, Wyoming. If it is successful it will free the United States from substantial dependence upon imported bauxite, the usual source of aluminium.

Anorthosite, a rock of the felspar type, occurs in abundance in the nearby Wyoming mountains. The first batch of about 15 tons of alumina to be produced is reported to be apparently of good quality, coarse in texture and low in silica. The Laramie staff is said to be optimistic about results.

Started during the war by the Defense Plant Corporation, the new plant was one of four units erected to experiment in the production of aluminium from material other than bauxite. Construction of the plant was stopped at the end of the war and it was put in a standby condition without ever being operated.

In 1951 the custody of the plant was transferred to the General Services Administration, which leased it to the Bureau of Mines for two years of experimental operation, with the option of one year's extension. The Bureau of Mines has completed the plant, installing a crushing unit, a water purification system and a fuel system for the firing of the kilns and boiler plant with either oil or pulverised coal. It has also reconditioned the equipment.

Before being able to produce the first alumina, test operations of the various units were tried out and modifications made when necessary. The lime-soda-sinter process uses anorthosite and limestone as raw materials.

All units of the plant have now been in operation and test operation is to continue until June 1954. The plant has a capacity for treating 700 tons of raw materials daily and will produce 60 to 70 tons of alumina a day. When in full production it will require a staff of 175 operatives. The main features of the plant are the administration and laboratory building, shop and warehouse, sintering, leaching and crushing plants, water well, tailings pond and storage facilities for anorthosite, limestone, coal, fuel oil, soda ash, molasses and alumina.

Dust explosions in factories

MANY industrial processes involving combustible materials cause dust clouds which can explode or cause outbreaks of fire. Problems of dust explosions in factories are being investigated at the Safety in Mines Research Establishment, Buxton. According to the report of the Fire Research Board, D.S.I.R., for 1952, during that year the Establishment tested 55 dust samples for explosibility. As a result a number of dusts were added to class 1—dusts which ignite and propagate flame readily on contact with only a low source of heat. The materials concerned include: Synthetic resins, feeding stuffs, wood dusts, aluminium flake, synthetic tanning powder, leather pigments, cellulose acetate, seed and grain cleaning dusts, dried grass, sulphonamide, sulphadiazine, locust bean kernel husks, extracted ground-nut meal, tea dust, blown zinc powder, pyrethrum, aluminium dust from the metal spraying process, diazo compounds and a dyestuff.

With the main objective of obtaining more knowledge of the processes occurring during the explosion of a dust cloud, the Establishment has continued to develop test apparatus, using up to the present dispersion-explosion tubes 3 in. in diameter. A closed-circuit system (similar in some ways to certain factory plant), in which a suspension of dust in air was maintained by rapid circulation, was found unsuitable, owing to a serious comminution of the dust, mainly during its successive passages round the bends of the apparatus, and to varying losses through lodgement on the fan rotor. More promising results have been given by a straight open-ended vertical tube (up to 10 ft. long), into which dust is allowed to fall freely from a calibrated feeder. An empirical relationship has been established between the rate of dust feed, the speed of induced air flow and the length of the tube. Experiments have continued also with 3 in. explosion tubes in 10 in. lengths using a variety of means of dispersing the dust charge with a view to finding the most effective method with any

given dust from the wide range of those handled in industry. Closed chambers of this type are appropriate for the quantitative determination of any of the parameters relating to explosibility.

Experiments with hinged vents for relieving the pressure produced by dust explosions have continued in a 30 in. gallery. Vents of two types were used in separate series of experiments, one made of light alloy with steel hinge straps and weighing 43 lb., the other of steel weighing 63 lb.; both were about 1 sq. yd. in area. Two kinds of explosions were produced with cork dust, one moderate in intensity and the other violent, by using different means for igniting the dust cloud in the gallery. In all the experimental arrangements, in which the vents were placed at various points along the gallery, the relief of pressure afforded by the hinged vent did not differ significantly from that afforded by a free opening in the same position. Comparison of the pressure-time records of explosions with cine-photographs of the movement of the hinged vent showed that the maximum pressure in the gallery occurred at the instant at which flame first appeared through the vent and before the vent had opened more than 40-45°. This observation led to experiments in which the angle of movement of the vent was limited by a framework to 45°, and it was found that no less relief was obtained than before.

More progress in de-salting research

EUROPEAN research on the demineralisation of salt waters has now assumed a clear-cut pattern. As reported in CHEMICAL & PROCESS ENGINEERING in May, the Working Party set up by the O.E.E.C. appointed a group of experts to study various de-salting processes. From the data collected by the experts the Working Party has now been able to decide which processes are the most suitable for co-operative development.

Four processes have been selected and four separate working groups will be established with the task of finding the right basis for co-operation between the various countries in each of these four fields. The task of establishing these working groups has been entrusted to those countries which have made most progress in the processes concerned. Thus, the working group to study *vapour compression distillation* will be set up by the U.K. France, after consultation with Germany, is to set up a working group on *ion exchange*, and is also entrusted with *solar distillation* research in Morocco. The fourth process, *electrodialysis*, will be the concern of the Netherlands. In each case research will extend to the de-salting of both brackish water and sea water.

For these four processes as exact an estimate as possible has been made of the cost per cu. m. of demineralised water and of the necessary investment in plants of two different capacities, *viz.* for 10 and for 1,000 cu.m. day. In the light of these figures the following conclusions can be drawn: For the de-salting of water with 1,000 or 5,000 p.p.m. Cl. the electrodialysis method seems to be the most economical. For the treatment of sea water the distillation and the electrodialysis method are more or less competitive. The same applied to both large and small quantities.

The cost price of the distillation method is scarcely affected by the initial salt content. On the other hand the cost price of both electrodialysis and the ion-exchange systems is very much affected by it. For high salt contents (sea water), the cost of demineralisation by means of ion-exchange is prohibitive.

Two other processes originally considered by the group of experts have now been rejected. One, high pressure distillation, is still in its infancy. Its chief drawback is that it cannot be carried out on a technical scale without a non-corrosive constructional material that must, moreover, be resistant to the high pressures required. For the time being only gold seems suitable. The other rejected process is separation by freezing-out, which is far too expensive for general purposes.

There is still no sign that the O.E.E.C. means to co-operate with the Saline Water Research Programme of the U.S. Department of the Interior, whose work was described in articles in our April and July issues. The American programme is inspired by aims similar to those of the O.E.E.C. and an exchange of data would undoubtedly prove rewarding.

Labelling hazardous chemicals

MANY chemicals present no special hazards in normal use, but the increasing use of chemicals for new and varied purposes has emphasised the need to warn handlers and users that some products need special care; information regarding the properties of products and the action desirable in the event of a leakage of the contents of a package may be helpful also to carriers. The most effective means of supplying such information and advice to the user is through the Technical Service Departments of the manufacturers, but a simple and uniform system of warning labels on containers provides valuable and continuous support at all stages in the passage from the maker to the ultimate user.

The Association of British Chemical Manufacturers has now issued a booklet, 'Marking Containers' (7s. 6d. inc. postage), which outlines a system of warning labels for hazardous chemicals. The system is limited to trade in the United Kingdom.

The booklet sets forth certain general principles for the preparation of warning labels and recommends specimen wording for a number of chemicals. The principles include a description of the legal position, a series of recommended standard phrases, and a detailed specification for the layout of the label. Specimen wording is given for over 200 chemicals together with an index to the most common synonyms.

This first list has been confined to chemicals and does not include compounded products such as insecticides or pharmaceutical preparations; it may be extended as experience is obtained of the working of the scheme in practice. The list of chemicals for which specimen wording is given is not complete, but with the general principles provides sufficient guidance for any manufacturer to prepare suitable wording for his product.

The types of containers for which this scheme is intended are single bulk containers, or outer containers wherein small containers of one chemical only are packed, passing in trade in the U.K. in quantities exceeding 6 pints for liquids or 8 lb. for solids, but excluding compressed and liquefied gas containers and road and rail tank wagons. For the time being the labels will be additional to those required by law or by carriers, but the possibility of integration is being examined.

The scheme has been approved by the A.B.C.M. Council and recommended for adoption by all members. It is to be hoped that it will be used generally by all manufacturers. The Chief Inspector of Factories recommends it for adoption as a code of practice by all manufacturers concerned.

CHEMICAL ENGINEERING CONFERENCE PAPERS

THE Chemical Engineering Conference held in London last month in conjunction with the Chemical Plant Exhibition, was sponsored by the Institution of Chemical Engineers and the Chemical Engineering Group of the Society of Chemical Industry. Papers presented ranged over a variety of subjects including evaporation, distillation, milk processing plant, formaldehyde production, chlorine production, etc. Newer materials of construction were also discussed and in the following pages we present in full the papers on plastics, and on carbon and graphite. We also publish an abridged version of the paper on the production of chlorine with especial reference to mercury cells. The purpose of the Conference was to stimulate discussion on important chemical engineering matters. We are glad to bring three of the papers before a wider audience and cordially invite readers to submit their comments for publication.

PLASTICS AND CHEMICAL PLANT

By V. Evans, M.Sc., F.R.I.C., F.P.I.

(*Prodorite Ltd.*)

In this paper the application of plastics to chemical plant is considered under four headings: Protective coatings, protective linings, corrosion-resistant cements, and plant and equipment built largely or entirely of plastics. Among the materials discussed are phenol-formaldehyde resins, furane resins, neoprene, Epoxy resins, polyurethanes, polytetrafluoroethylene, rigid PVC, polythene, modified polythene and synthetic resin-glass fibre combinations. Although the author has had to be selective, he has nevertheless produced a surprisingly comprehensive survey of this large and expanding field.

CONSIDERING the enormous amount of research devoted to polymer science, it is a little surprising that recent progress in the application of plastics to chemical plant has been largely concerned with materials known in most cases for several years. In fact, there has been no outstanding entirely *new* plastic developed for some considerable time. This observation does not, of course, include materials now being studied in the laboratory and which may eventually have very important applications in the chemical plant field. On the other hand, such a situation does give time for the development of suitable application techniques of existing materials. Consequently this paper is largely concerned with developments in the applications of plastics which have been known in many cases for several years. These applications have now become very numerous and it is only possible to make a selection of the more interesting ones, particularly as the term 'chemical plant' can be interpreted widely to include services, chemical-resisting flooring and similar ancillary equipment. Some attention has also been given to materials of great potential interest for which application techniques have either not been fully worked out or are still in the experimental stage.

It is difficult to divide applications conveniently into water-tight compartments, so for the purpose of this paper an arbitrary division has been made into four sections:

(*a*) Protective coatings.
(*b*) Protective linings.
(*c*) Corrosion-resistant cements.
(*d*) Plant and equipment constructed largely or entirely in plastics.

This division is unsatisfactory in some respects, *e.g.* the distinction between coatings and linings. However, the distinction is made on the basis of thickness: *coatings* are limited to comparatively thin films up to about 15 mils, whereas *linings* range from about 15 mils to quite substantial thicknesses. There is also a rough division according to the technique of application: coatings are generally applied by spray or brush, whereas linings are applied as sheets. Even with these explanations it is obvious that a certain amount of overlapping is inevitable.

During the last few years the application of plastics to chemical plant has not only developed very considerably but a large amount of experience has been gained which has enabled the limitations of these materials to be defined more clearly. The tendency to regard plastics as a universal cure-all for difficult situations has largely been replaced by a more sober and informed realisation of their possibilities. Shortages of stainless steel and other special corrosion-resistant alloys have been less acute and this factor has also helped to place plastics in their proper position, that is as materials of construction possessing valuable and in some cases unique properties, standing firmly on their own merits and not as mere substitutes for materials in short supply.

PROTECTIVE COATINGS

Paints and similar coatings for the protection of structural steelwork and other external uses will not be discussed, as it is felt that a complete paper could easily be devoted to these applications alone. Nevertheless, several of the materials to be mentioned in this section have important applications in such fields. An interesting division of conditions of exposure of protective coatings has been given[1] which may be conveniently summarised as under:

Class I. Coating subjected to continuous and direct contact with corrosive liquids.
Class II. Coating subjected to high concentration of corrosive fumes with frequent splashing by corrosive liquids.
Class III. Coating subjected to high concentration of corrosive fumes with little or no splashing by corrosive liquids.
Class IV. Coating subjected to moderate concentrations of corrosive fumes only.

As paints in the normal way are excluded from this paper, it will be seen that Classes I and II will be given major consideration, but Classes III and IV are met with in applications such as ducting and exhaust systems and similar equipment.

Although coatings of thicknesses varying from 5 to 15 mils are often resistant to a wide range of very corrosive chemicals, they are generally used under only moderately corrosive conditions because of the danger of mechanical damage causing a break in the continuity of the lining. Frequently the base metal is mild steel and the danger of such a happening is obvious. Linings of this type are usually electrically tested at the factory before dispatch and any later mechanical damage can be repaired successfully *in situ*. Among the conditions for which these linings are suitable are storage and processing of beverages, foodstuffs, solvents, special fuels, fine chemicals and pharmaceutical products. Another application is in the

lining of ships' storage tanks for edible oils, etc.

Phenol-formaldehyde resin coatings still very largely hold the field at present in this country and among recent applications may be mentioned their use as coatings for large storage tanks to hold phenol where absence of colouration is important, coatings for worm conveyors and troughs, gasometer bells and refueller tanks for airfields.

Furane resin coatings are also used in the U.S.A., but so far have been little used in this country. They have the advantage of excellent resistance to alkaline conditions, but otherwise their characteristics and chemical resistance are much of the same order as the phenol formaldehyde resins. There is less need for protective linings in alkaline conditions than in acid conditions, and this factor, together with the dark brown or black colour of the linings, possibly accounts for the small headway they have so far made.

Neoprene coatings have also made considerable headway in the U.S. and provide very good chemical resistance to all the common inorganic acids, alkalis and also to oils. In addition they have much better heat resistance than ordinary rubber coatings and have been used successfully at temperatures up to 115°C. for linings to tanks and vessels.[1]

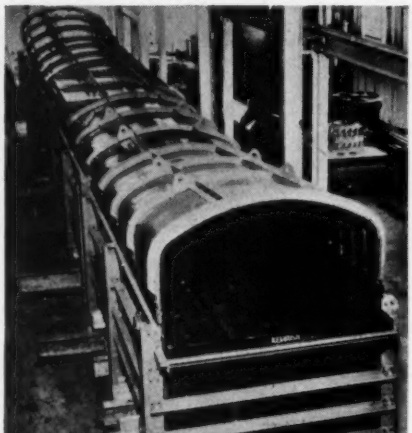
Epoxy resins

Among the newer coating materials may be mentioned the Epoxy resins, based on the combination of epi-chlorhydrin and bisphenol. These products require further reaction with other substances such as special phenol-formaldehyde resins to give hard, tough but yet flexible coatings having wide chemical resistance. At the moment rather high stoving temperatures of the order of 200°C. are needed to obtain maximum chemical resistance, but work is being actively pursued with a view to obtaining similar properties with lower stoving temperatures. Even at the moment low-temperature cures can be obtained, but with somewhat reduced chemical resistance, by the use of certain amines. Coatings based on the Epoxy resins have already been used for drum and tank linings and for external protection of chemical plant.[2, 3, 4]

Polyurethanes

One of the most interesting developments in the coating field is the use of the polyurethanes. Materials can be formulated to give two components which, when intimately mixed, react chemically in the cold to give tough chemical-resistant polymers. No water or other material is evolved in this process and by using solutions of the two components in suitable solvents a product is obtained which, applied by brush and spray, gives a tough, chemical-resistant coating with many potential uses. Coatings of this type have improved flexibility and are resistant to a wide range of acids, most alkalis and many oils and solvents. For many purposes the coating obtained under atmospheric temperatures is quite suitable, but for increased chemical resistance moderate stoving up to temperatures of about 80 to 120°C. are used. Normally several coats are applied to give a final film thickness of some 9 to 12 mils.

Although stoving at elevated temperatures is normally not essential, it has been found advisable to give a mild heat treatment in the case of enclosed vessels at about 25°C. The elimination of normal stoving temperatures opens up a very wide field of application, particularly for *in situ* work. For instance, the coating of ships' tanks for storage of edible or fuel oils is now being carried out with this material and the lining of chemical plant in suitable cases can be envisaged. Another interesting application is the lining of vessels which are lagged with material sensitive to or damaged by moderate temperatures, so that the lining can be carried out without the expensive process of removing the lagging. Another field of use is in the external protection of vessels and plant, although it does not strictly come into the scope of this paper. Both road and rail tankers for the transport of liquids such as milk have also been lined with this material.[5, 6, 7]



[Photo: Kestner Evaporator & Engineering Co. Ltd.

Continuous strip pickling tank in phenol-formaldehyde resin-asbestos composition.

Among the more recently developed coatings are the silicones, which have not as yet made much progress into the coating field except for temperature resistance, because their chemical resistance, although quite good, is equalled or surpassed by several other coating materials.[8]

Polytetrafluoroethylene

Much research has been devoted to the development of polytetrafluoroethylene coatings, but so far success has been very limited. Usually this polymer has been applied as dispersions in inert organic solvents and, after evaporation of the solvent, heat has been used to sinter or fuse the polymer. Unfortunately, this process is very difficult and the coatings so obtained are neither pinhole-free or even. Nevertheless, some use has already been made of these linings by virtue of the fact that liquids do not wet or adhere to them. Thus polytetrafluoroethylene has been used for coating the interior of vessels which contain viscous liquids and normally require careful cleaning out before the introduction of a fresh batch. By using a coating of polytetrafluoroethylene applied as described above, viscous liquids can be drained from the vessel completely and avoiding the time-consuming cleansing operation formerly necessary. This useful result is achieved even when the coating contains pinholes and other discontinuities. Another similar application has been to coating rollers.[9, 10]

Polytrifluorochloroethylene is somewhat less difficult to work with than polytetrafluoroethylene, yet its chemical resistance is only slightly inferior. So far it has been developed mainly in the U.S. and Germany. It can be obtained in the form of sprayable dispersions in organic liquids and has been applied to the linings of small vessels in this form. Some four to five coats are normally applied with a short stoving period at 250°C. and finally the complete coats are stoved for several hours at this temperature to give a fused even coat.[11, 12]

PROTECTIVE LININGS

As already indicated, the distinction between coatings and linings is not entirely governed by thickness, and a more accurate description of linings might well be made. Briefly, for the purpose of this paper, linings are limited to materials available in sheet or foil form and to those applied in appreciable thickness by trowel or similar means.

There is, as yet, little experience of the latter types of linings in this country, but experimental work is going ahead. They include the so-called 'plastigels' which are prepared from plastisols (dispersions of thermoplastic polymers such as PVC and PVC copolymers in plasticisers) by the addition of gelling agents such as metallic soaps. Plastigels are putty-like in physical properties and can be spread in appreciable thicknesses by trowel or spatula to form linings for tanks and similar plant. After application, stoving at 150 to 180°C. is needed to convert the lining into a tough, rubbery material. With linings of this type there is always some likelihood of plasticiser leaching out, but these appear to offer possibilities as alternative linings to plasticised PVC in sheet form.

Another lining material applied in a similar manner is a development of the well-known phenol-formaldehyde resin cements. Reports of this type of material have been received from the U.S. and

Photo: Prodorite Ltd.

Formaldehyde transport tank with phenolic-type resinous lining.

Germany and it appears that, by additions to phenol-formaldehyde resin cements, self-setting mortars and plasters are obtained which, on hardening, have a certain amount of flexibility and elasticity. By the use of priming coats and application of mild heat, coatings are claimed for floors and both metal and concrete tanks and vessels. One application to concrete has been for lining large storage vessels to hold diesel oil and similar fuels.

Turning to materials available in sheet and foil form, rigid PVC still holds a prominent place in this field.[13] Apart from the extended use of PVC foil (about 0.5 to 1 mm. thick) as bonded linings for tanks and chemical plant and also loose linings of thicker PVC sheet, a very interesting development has been the introduction of a combination sheet. This comprises a normal rigid PVC sheet some $\frac{1}{16}$ in. thick, to which is firmly adhered a plasticised PVC sheet of similar thickness. For lining purposes the unplasticised PVC is placed so as to be in contact with the liquid in the tank or vessel and the plasticised PVC faces the walls of the vessel. The advantages of this arrangement are that plasticised PVC is bonded to metal more readily than rigid PVC, adhesion is obtained without the aid of heat and it provides a flexible backing to the rigid PVC.

Rigid PVC foil is now coming into use as an underlay for chemical-resistant floors in a similar way to polythene foil. It has the advantage over polythene of a greater resistance to puncture, a matter of great practical importance.[13]

Polytrifluorochloroethylene is now available in the U.S. in sheet and foil form and in Germany as foil. Extruded foil is available 5 to 10 mils in thickness and sheets 30 to 50 mils in sizes approximately 32 in. square. This material is not so difficult to fabricate as polytetrafluoroethylene and can be heat-sealed and welded. Reports of the use of the material for linings of vessels and tanks have been received, but no details are available. Another use of the film has been as an impervious membrane behind a corrosion-resistant brick lining in acid towers. With its exceptionally good chemical resistance at fairly high temperature, further use will undoubtedly be made of this remarkable material.[11]

A further American development has been the production of a chlorosulphonated derivative of polythene. This material behaves as a rubber and can be vulcanised by suitable means. Chemically it resists ozone and strong mineral acids, oils, glacial acetic acid and sodium hypochlorite solutions. Not only is the chemical resistance good, but flexibility is maintained even after boiling in 70% nitric acid and immersion in liquid chlorine. Details of application are not yet available, but if suitable techniques can be worked out, the lining of tanks and chemical plant is a certain development.[14]

CORROSION-RESISTANT CEMENTS

Corrosion-resistant cements based on resinous materials are certainly being more widely used and to some extent are replacing the older cements such as the well-known silicate, sulphur and bitumen types. This movement is well marked in America and is slowly gaining ground in this country. As in many other fields, progress has been maintained largely by slow, steady improvement of existing types of cement rather than by a spectacular advance brought about by the introduction of an entirely new cement having outstandingly superior properties.

Among the more recent developments may be mentioned the use of china clay as an inert filler for use in phenolic and furane-resin-type cements. By this means cement mortars are obtained which are very easily mixed and applied. These cement mortars also have very desirable rheological properties in the sense of 'staying put' when applied to brickwork, tiling, etc., with no tendency to flow.[15]

Interesting developments in the modification of the well-known sodium silicate cements by plastics materials are disclosed in a recent patent application. This comprises mixing a suitable thermoplastic such as polythene or even polytetrafluoroethylene with the cement powder before admixture with the sodium silicate solution and, after the normal setting and hardening period, applying sufficient heat to fuse the thermoplastic material. In this manner the individual particles of filler and gelled sodium silicate became coated with the thermoplastic used, with considerable improvement in the overall chemical resistance and impermeability of the cement. Although there are obvious application difficulties, this development offers obvious possibilities in the construction of chemically-resistant brickwork.

The well-known furane resins based on the acid condensation of furfuryl alcohol are rather expensive and recent work on the production of resins from the cheaper furfuraldehyde may eventually lead to less expensive cements of this type. It has been found that small additions of furfurin or methyl furan to furfuraldehyde enable promising resins to be obtained by acid condensation of this material, in contrast to the weak, spongy product obtained from furfuraldehyde alone.[16] Nevertheless, the use of synthetic resin cements based on furfuryl alcohol is increasing and extensive use has been made of these cements as jointing mortars for brickwork in large continuous-strip pickling plants. Use has also been made of furane resin cements trowelled as a mortar on to steel mesh as membranes for tank and vessel linings for use behind brick or tile linings set in suitable corrosion-resistant cements. In this application a layer of glass-fibre impregnated with a furane resin is interposed between the brick lining and the brick lining and the trowelled membrane.

The American technical press has mentioned cements based on epichlorhydrin resins, but little specific information is available. Superior adhesion to brickwork has been claimed for these cements and such an achievement is extremely interesting. The same report quotes these cements as having improved resistance to nitric acid solutions up to 15% strength. Reports are now available of a cement based on epichlorhydrin resin in a liquid form used with inert filler and a liquid amine as curing agent. At present the chief limitations of the synthetic resin cements are their poor resistance to oxidising acids and similar substances and the moderate adhesion to ceramic ware; any appreciable improvement in these aspects will be of considerable importance. Papers dealing with corrosion-resistant cements based on synthetic resins have recently been published and give an up-to-date survey of this field,[17, 18] whilst recent developments have been reviewed in *Industrial and Engineering Chemistry*.[19]

Corrosion-resistant cements are being

extensively used for jointing all kinds of structural units in ceramic ware for the construction of floors, gutters, drainage channels walls and for tank and vessel linings of almost any shape or size. In the case of linings they are usually employed with an impervious membrane behind the corrosion-resistant brick or tile lining and in many instances the impervious membrane is a plastic material such as plasticised PVC, polyisobutylene or one of the synthetic rubbers.

PLANT AND EQUIPMENT CONSTRUCTED LARGELY OR ENTIRELY IN PLASTICS

PVC

Rigid PVC is still one of the most versatile plastics used for this purpose and considerable development has taken place in its application. Quite large pieces of plant and equipment are now being fabricated in this material, including exhaust ducting and ventilation ducting of all shapes and sizes, absorption towers and gas-washing towers, rotary drum filters and every variety of tank, tray and similar articles. Smaller but equally useful items include scoops, shovels, pickling and dipping baskets, plating drums and fan impellers and casings. Extruded pipes, valves and tubes in rigid PVC which have been available in Germany and some other countries for several years are now being produced in this country, and very considerable use will undoubtedly be made of these valuable products. Apart from the wide variety of pipelines that are available, cooling coils have been fabricated in this material where temperature conditions allow. The heat resistance of rigid PVC does, of course, limit application possibilities to maximum temperatures of 30 to 60°C., but even with this restriction use is increasing.[13] One of the most remarkable applications of rigid PVC has been carried out in Germany. A large brick chimney stack some 270 ft. high had been badly damaged by chemical fumes; to renew the masonry was very expensive, consequently a subsidiary stack approximately 18 in. in diameter and constructed in rigid PVC was run alongside the main stack. The PVC fume stack was made by using short cylindrical sections with a top socket, so that the sections could easily be fitted on top of each other in a similar way to normal spigot and socket pipes. Polythene rings were placed between the 'spigot and socket' to centre the sections and provide a tight but yet flexible joint; as an additional protection an 'umbrella' of rigid PVC was welded to each section to cover completely the socket joint. The whole PVC stack was attached to the brick chimney by mild-steel supports sprayed with polythene and anchored into the brickwork.[20]

Apart from fabrication from sheet and extruded sections, rigid PVC can also be moulded, blown and pressed and, by drawing the softened sheet over formers, quite 'deep drawn' articles such as small vessels, trays and similar products can be made. By the use of copolymer of PVC and polyvinylidene chloride, the production of articles by the 'deep drawing technique' has been considerably facilitated and great strength and dimensional stability can be imparted.[21]

Irradiated polythene

Polythene has perhaps been somewhat displaced by rigid PVC for work in the chemical field, but it is still finding considerable use for the fabrication of ducting *in situ* where the comparative ease with which it may be welded is an important feature. Another application which continues to widen is the use of extruded polythene pipes for the construction of effluent drainage from chemical plant and works. Very great interest has naturally been aroused by the work carried out on the irradiation of polythene in the atomic pile and also by high-voltage X-rays.[22, 23] By this means the normal structure of polythene consisting of long, linear, hydrocarbon chains has been modified by a greater or lesser degree of cross-linking between these chains. This results in the softening point being raised, a reduction in solubility in solvents and an increase in strength and chemical resistance. Much detailed investigation is required before the practical aspects of this remarkable discovery can be fully appreciated, but it may well have far-reaching effects in the chemical plant field. Already small polythene bottles are being exposed to electron streams from high-voltage X-rays for quite brief periods with the result, according to reports from the U.S., that the bottles can be steam sterilised without harmful effects.[24] The suggestion has been made that irradiated polythene forms a new kind of plastic material intermediate between the normal thermoplastic and thermosetting definitions.

Both polytetrafluoroethylene and polytrifluorochloroethylene are finding extended use as gaskets, washers, sealing discs and diaphragms for situations which call for their exceptional chemical resistance. Another application of the latter polymer has been for the construction of sight windows in chemical plant. Silicone rubbers are also being used as gasket material for higher-temperature conditions and there is no doubt that the new chlorosulphonated polythene will also be used for gaskets and similar applications.

Asbestos-filled PF resin

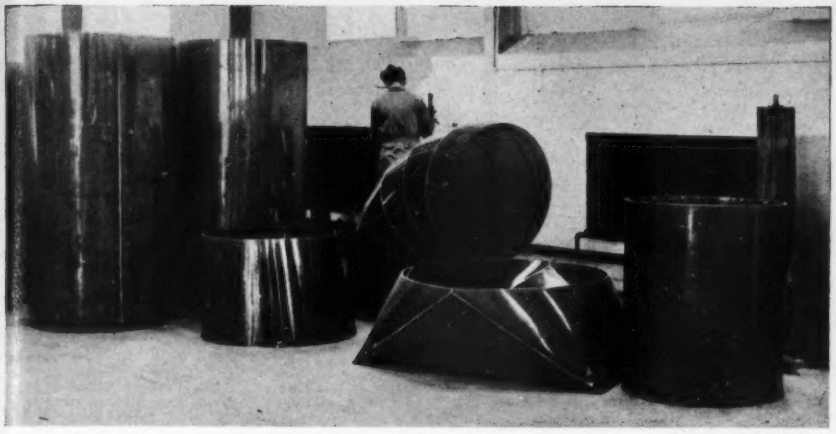
Turning to the applications of thermosetting materials, more use is being made of the well-known proprietary material which consists essentially of an asbestos-filled phenol-formaldehyde resin. This material is built up using comparatively cheap and simple moulds to quite large structures. Amongst the many pieces of plant constructed with the aid of this material may be mentioned tanks and vessels of all types and sizes, including pickling tanks up to 60-ft. long made in 10-ft. sections. Other applications include steam injectors for corrosive solutions, rotary dyeing machines, fans, fan casings, ducting, absorption towers, chimneys, filter presses, pipes and valves.[25] By the use of furane resins in this type of material, the chemical resistance has been widened to withstand most alkaline liquids including caustic alkalis.

Glass fibre and plastics

Considerable attention has been devoted in the last few years to materials based on combinations of various thermosetting synthetic resins with glass fibre in various forms. Such combinations allow fabrication of quite large and complex articles to be carried out with relatively simple and inexpensive equipment. High pressures are unnecessary, in fact for many purposes virtually no pressure at all is required, the technique comprising 'laying up' glass-fibre cloth or mat on simple moulds and impregnating with a catalysed resin which hardens at normal temperatures. In this way quite elaborate structures can be readily produced and, because of the inexpensive equipment used, 'one-off' articles are economical propositions.[26, 27]

At the present time mainly unsaturated polyester resins are being used in this work and, although their chemical resistance is limited, they are resistant to many acids of moderate and dilute concentrations and to rather dilute alkaline solutions. On the other hand, the strength and higher temperature resistance of glass-fibre polyester resins offer considerable advantages over the thermoplastic materials. Already use has been made of these products for all kinds and sizes of ducting, for electroplating tanks, many other tanks, vessels, chimneys and pipes. Plant has been designed in the U.S. for the continuous production of pipes. As an example of what has already been achieved in the U.S. may be mentioned a large tank used in the manufacture of aluminium sulphate containing acid solutions of this compound at 115°C. The tank was constructed of sections bolted together, the dimensions being 14½ ft. in diameter by 8 ft. in depth, the wall thickness being ⅜ in. Another interesting example is an exhaust fume stack some 22 ft. high by 2 ft. 6 in. in diameter. This material is obviously destined to play a very important part in the construction of chemical plant, in spite of quite important limitations in the chemical resistance. Nevertheless, even more interesting possibilities are presented by the utilisation of alternative thermosetting resins of wider chemical resistance such as epichlorhydrin, and furane resins and of greater heat resistance by the silicone resins.

Another interesting development in the use of thermosetting resins is the use of an asbestos paper or fabric impregnated by phenol-formaldehyde resins. Fabrica-



[*Photo: Prodorite Ltd.*

Exhaust ducting fabricated in rigid PVC.

tion techniques using this material have been worked out by the Royal Aircraft Establishment, Farnborough, for certain aircraft applications, but there is no doubt that the material is of potential interest in the chemical plant field. In some applications it has points of similarity to the glass-fibre/polyester-resin technique in that it is 'layed up' in layers on simple moulds or formers without the use of high pressure, but it does require mild heat treatment to cure the resin. Structurally it is claimed to possess greater stiffness than glass-fibre polyester-resin combinations and, although chemical resistance to alkalis will not be so good as the polyester resins, the resistance to acids should be greater. Here again intriguing possibilities are opened up by the substitution of alternative resins to phenol-formaldehyde types.[28]

In this paper an attempt has been made to give some account of recent developments in the application of plastics to chemical plant and to developments in plastics which are likely to have applications in this field. Obviously much has been left unsaid and a certain amount of selection of material has been necessary in order to avoid undue length, but it is obvious that plastics now play a very important role in the construction of chemical plant. In view of the many recent developments in plastics techniques, it is certain that they will be utilised to an even greater extent in the future.

In conclusion the author wishes to thank Dr. Himsworth of Imperial Chemical Industries Ltd. for certain information, Mr. G. H. Black of Kestner Evaporator & Engineering Co. Ltd. for information and the loan of photographs and to the Directors of Prodorite Ltd. for permission to present this paper.

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Polyester handbook. The rapid expansion of polyester plastics, the new techniques and the many novel applications evolved have attracted not only considerable attention but also considerable bewilderment in the plastics trade generally. The purpose of a 70-page illustrated handbook published by Scott Bader & Co. Ltd. is to provide facts and figures which will clear up these difficulties. After a section on the chemistry and general characteristics of polyesters, the booklet deals in turn with laminating, moulding and casting applications, as well as special applications such as corrosion investigation and vacuum impregnation. A further section deals with fillers and pigments and finally there is a chapter on the properties of polyesters.

Spiral heat exchangers

Rubber spiral heat-exchanger units have been found an effective new approach to the problem of heat transfer. Instead of following an essentially straight-line path, as in the ordinary jacketed heat exchanger, the cooling medium is forced into a spiral path, with the result that, for a given input of cooling water, the linear flow rate may be as much as four times greater than in conventional units.

Heat transfer coefficient

In tests on a glass-lined condenser, it was found that, with a conventional high-velocity nozzle, the overall heat transfer coefficient at a cooling water rate of 20 gal./min. was 78 B.Th.U./hr./sq.ft./°F. With the new spiral unit, the coefficient at the same rate of water input jumped to 110. At a cooling water rate of 40 gal./min., the heat transfer coefficient was increased from 95 B.Th.U./hr./sq.ft./°F. in the case of the high-velocity nozzle to 120 with the spiral unit. In an application where a heat transfer coefficient of 95 is required, only 10 gal./min. of cooling water is needed if the spiral insert is used, instead of 40 gal./min. with the high-velocity nozzle.

Construction of new units

The new heat-transfer units, devised by an American consulting engineer, Dr. F. R. Gross, are described in *Industrial and Engineering Chemistry* (1953, **45** (8), 114). They take two forms, one type consisting of inserts that are installed on the inside surface of such equipment as cooling rolls, flakers and glass-lined condensers, while the other type consists of jackets that are mounted on the outer surfaces of pipes, tanks and other equipment. Made of rubber, the inserts and jackets are equipped with spiral ribs that press firmly against the surface to be cooled, thus forcing the liquid into the required helical path. For normal use, between −20 to +200°F., the ribs are made of GR-S rubber. For temperatures between 200 and 260°F., butyl rubber is recommended. Where a hot oil is circulated through an insert at, *e.g.* 350°F., a material such as polyacrylic rubber is usually preferred. Although silicone rubber might be used, its cost at present is prohibitive.

In general, the ribs are attached to shells of cotton fabric, glass fabric, or steel depending on the temperatures involved and the amount of flexibility required for fitting the units.

Dr. Gross believes that the savings which result from improved operating performance—such as low water consumption, higher speed of operation and better product—more than cover the cost of the new installations. Furthermore, in special applications, such as in jacketed glass-lined piping, the new units are definitely cheaper than conventional heat-transfer equipment, according to the inventor.

CHLORINE PRODUCTION WITH MERCURY CELLS

Recent Developments

By L. R. Thomas, B.Sc., D.I.C., A.M.I.Chem.E., A.R.I.C.

(*Monsanto Chemicals Ltd.*)

Diaphragm cells account for the greater proportion of the world chlorine output at the present time, particularly in the U.S. where this type of cell has reached a high level of efficiency and construction through the development of the latest Hooker model. In Europe, however, mercury cells are more widely used and have been developed further, particularly in Germany where they are preferred to diaphragm cells. It is significant also that since 1945 interest in the mercury cell has increased in the U.S. and it has accounted for a considerable proportion of new chlorine manufacturing capacity installed in that country recently. In this paper the author describes the basic principles and characteristics of present-day mercury cells. He concludes by predicting that there will be increasing general use of the mercury cell for chlorine production.

IT is not intended in this paper to present a historical review of the development of chlorine cells nor to discuss diaphragm cell details, but rather to indicate the basic principles and characteristics of present-day mercury cells. It should be remembered that the principles of mercury cell operation have been known for a long time and that developments in recent years have been mainly concerned with improvements in operating technique, cell capacity and constructional details. However, before describing the various types of mercury cell, it is felt that a limited discussion of the basic principles involved will provide a background to the design features of these cells.

Basic principles of mercury cells

In the electrolyser, a saturated brine solution is electrolysed between graphite anodes and a moving mercury cathode. At a sodium amalgam surface, sodium discharge requires a cathode potential of -1.8 v. and hydrogen discharge -0.6 v. The high hydrogen over-voltage of -1.3 v. on sodium amalgam further increases the hydrogen discharge potential to -1.9 v., *i.e.* more negative than the sodium discharge potential. Further factors facilitating sodium instead of hydrogen discharge are the high ionic ratio of sodium ion to hydrogen ion, and the continual removal of sodium as amalgam which lowers its electrolytic pressure. However, hydrogen discharge always takes place to some extent, and is increased when the sodium ion concentration falls too low, or the sodium concentration in the amalgam becomes too high, or when the hydrogen over-voltage is reduced too far. Hydrogen over-voltage is lowered by increased temperature, decreased current density and particularly by the presence of certain metallic impurities.

In considering the potential differences in a mercury cell, the anode potential is the most important, since it increases with increased current density. This item is the main limiting factor of the capacity of one given cell, and future improvements in the total cell voltage can be expected only by the possibility of diminishing the anode potential by means of improvements in anode materials and design. The electrolyser voltage can also be decreased by reducing the interelectrode gap and amalgam concentration, and by increasing the concentration, temperature and rate of circulation of the electrolyte. Some of these factors influencing electrolyser voltage must be balanced, however, against their effect on the hydrogen over-voltage at the cathode.

From the above it is evident, therefore, that the most important factors influencing the electrolysis operation are current density, final amalgam concentration, continuity of mercury flow, interelectrode gap and the concentration, temperature and purity of the electrolyte.

High current density will decrease the size and cost of the electrolyser, but will increase the voltage drop and energy consumption. When designing an electrolyser these factors must be balanced. The distance between anode and cathode should be as small as possible to reduce energy loss, the limit being determined by the incidence of direct attack of sodium amalgam by the chlorine bubbles. Mercury cell anodes should be made of high-quality graphite containing no Va, Cr or Mo.

The presence in the brine of metallic impurities such as Va, Cr, Ni, Ba, or Fe in the presence of Mg, will decrease the hydrogen over-voltage and cause hydrogen evolution at the cathode. High calcium concentration does not increase the hydrogen discharge, but is likely to give calcium sludge deposits in the electrolyser and thus necessitate more frequent cleaning of the cell. Sulphates increase anode graphite consumption and decrease energy efficiency. Chlorates in the brine also increase anode graphite consumption, but are not likely to be present if an acid brine is used and complete dechlorination of recycle brine is carried out before treatment.

In the decomposer, an electrochemical reaction occurs in which sodium amalgam acts as an anode and is short-circuited to an iron or graphite cathode, the electrolyte being sodium hydroxide solution. Sodium is ionised and goes into solution at the anode, hydrogen ions from the aqueous electrolyte are reduced at the cathode and the remaining hydroxyl ions react with the sodium to give caustic soda. If an iron cathode is used it is supported a small distance away from the amalgam to prevent its surface being amalgamated and destroying its activity. It is usual, therefore, to use a graphite cathode, since it can be placed in the amalgam without its surface being amalgamated.

The rate of amalgam decomposition is governed by the effective current density in the decomposer, the temperature and internal resistance of the caustic, and the type of graphite used. Since practical considerations require a concentrated caustic soda solution and a dilute amalgam, the rate of decomposition is increased by exposing a large contact surface to decrease the current density, by having the solution force its way in a thin film between amalgam and graphite surfaces to minimise resistance drop and by operating at a high temperature. Contact time is also an important factor, since the amalgam must remain in contact with the graphite long enough to be stripped of sodium.

Electrolyser types

Electrolysers may be broadly classified as follows: (1) Horizontal electrolysers (plate-bottom types and strip-bottom types); (2) vertical electrolysers (rotating-cathode type and falling-film type).

The majority of mercury cell installations use horizontal electrolysers, which

have been developed to a high level of efficiency in recent years. In general, the developments have taken the form of engineering design improvements and have covered such items as anode design and adjustment, improved design of covers, improved materials of construction, prevention of mercury losses and problems associated with increased current densities.

Compared with horizontal electrolysers the vertical rotating-cathode electrolyser is still in the development stage and has the disadvantages of lower electrical efficiency, higher concentration of hydrogen in the cell gas and higher unit consumption of graphite and mercury. However, it is fairly certain that work is in hand to overcome these defects which, if successful, will place the vertical cell in an advantageous position with respect to initial capital investment, because of its low mercury inventory and low floor space requirements.

(1) **Horizontal electrolysers.** Although individual horizontal electrolysers may differ in the choice of constructional material and in other minor details, the fundamental difference lies in the method used for establishing electrical connection between the steel trough and the flowing mercury cathode.

The plate-bottom type of electrolyser has its floor lined in the same way as the trough sides, and the electrical contact is made through circular or rectangular steel plates connected through the bottom lining to the steel trough. It is usual to set the steel cathode plate about $\frac{1}{8}$ in. lower than the lined bottom of the trough; this ensures that the plate is always covered with mercury when the flow stops or is unevenly distributed over the bottom. With this protection there is less risk of high hydrogen discharge owing to bare spots on the steel cathode plate, and acid cleaning of the plates is not as vitally important as with the strip-bottom cell.

The strip-bottom type of electrolyser has little or no lining on the trough floor, the bare steel bottom giving a direct electrical connection with the mercury. The trough bottom is machined to give a smooth surface, and must be given periodic level checks and dilute acid cleanings to maintain the even flow of mercury and prevent the incidence of bare spots.

Strip-bottom electrolysers are easier and cheaper to construct than plate-bottom types and are probably less susceptible to mercury leakage troubles. On the other hand, bottom electrolysers can tolerate greater concentrations of impurities in the brine and are less likely to give high hydrogen evolution in the event of uneven or interrupted mercury flow.

The choice of constructional material for the lining of modern horizontal electrolysers lies between rubber and granite. As yet there is no specific answer as to which lining is most economical; either may be cheaper in a given case. Longer life, smoother surfaces and better thermal insulation are claimed for granite linings, although no conclusive figures as to average life are available.

Anodes are usually suspended through the trough cover and may be individually or collectively adjusted, depending on the type of cell. The latest trend is to make the anode plates adjustable during operation and thereby keep the voltage drop to a minimum. The design of graphite anodes does not differ greatly, the latest types being grooved or perforated to allow easier escape of chlorine. Grooving of the anodes also helps to reduce the anodic current density.

(2) **Vertical electrolysers.** Vertical electrolysers are still considered to be in the development stage, although two or three plants in Germany are using the rotating-cathode type for large-scale production of chlorine. The vertical rotating-cathode type of electrolyser works on the principle that a rotating vertical steel disc with the lower part immersed in a mercury bath will transport a film of mercury about 1 mm. thick when electrolysing current is applied. As the disc surfaces rise from the mercury bath, the mercury tends to flow downwards owing to gravitation and thus forms a fluid cathode surface. This mercury film must completely cover the steel discs to minimise hydrogen evolution. The anode adjustment problem, together with the susceptibility of the rotating discs to magnetic distortion, constitute the most important mechanical drawbacks of this type of electrolyser.

The vertical falling-film mercury electrolyser was also developed in Germany, but has not been used on a commercial scale for production of chlorine. The cathode of this unit consists of an outer circular tube about 6 ft. high whose inner surface is completely covered with a falling film of mercury. A cylindrical perforated anode is arranged inside the outer cathode tube, and this anode is fitted with a PVC diaphragm on the outside to prevent the rising chlorine bubbles reacting with the sodium amalgam and reducing the current efficiency. Such an arrangement takes up very little floor space, but in its present form has the disadvantages of limited height and lack of anode adjustment facilities.

Decomposer types

Decomposers may be broadly classified as follows: (1) Horizontal decomposers (rectangular-trough type and closed-tube type); (2) vertical decomposers (single-stage tower, single-stage mercury-flooded tower and two-stage tower).

The horizontal decomposer has the advantage of producing graphite-free caustic, thus eliminating the need for caustic filtration, and its auxiliary power cost will be less because of the low-mercury pumping head. On the other hand, the vertical decomposer has the advantage of compactness, smaller mercury hold-up, less frequent cleaning is necessary, and the unit is more easily adapted for manufacture of 70% caustic soda.

(1) **Horizontal decomposers.** Horizontal decomposers are mounted below or at the side of the corresponding electrolyser; both types operate on the same principle. The advantages of the closed-tube type are its ease of construction, its adaptability for thermal insulation and its freedom from leaks, whereas the rectangular-trough type has the advantages of easier cleaning facilities and better graphite positioning.

The most important feature of the horizontal decomposer is the galvanic grid, which is composed of a single layer of perforated and grooved graphite blocks, or graphite plates bolted together and standing on end. These grids are laid on the trough bottom with the grooves parallel to the mercury flow.

Horizontal decomposer troughs are usually made of steel or cast iron, the latter being more difficult and expensive to construct, but are preferred where caustic soda with very low iron content is required. Rubber-lined steel troughs have also been used for the same reason and to eliminate leakages at the welds owing to caustic embrittlement.

Standard horizontal-type decomposers are usually used for producing up to 50% soda solution only. For producing more concentrated solutions the decomposer length has to be increased by about 50% and the walls must be well insulated.

(2) **Vertical decomposers.** Vertical decomposers are usually made of steel, although cast-iron and rubber-lined steel towers have been considered for the same reasons indicated under horizontal decomposers.

The decomposer cathode is usually in the form of activated graphite lumps of $\frac{1}{8}$ to 1 in. size. In the latest types of decomposer these lumps are contained in a steel basket to make for easier removal. To prevent excessive breakdown of the graphite it is essential to keep it tightly packed, and in some of the latest decomposers this is achieved by using spring-loaded plates pressing down on the top of the packing. With vertical decomposers there is always a tendency for the caustic solution to contain fine graphite particles formed by abrasion which have to be removed by filtration, but graphite contamination can be minimised by using a suitable grade of graphite and by ensuring a minimum of movement in the packing.

The most common type of vertical decomposer in use for producing 50% caustic solution is the single-stage tower, non-flooding with respect to mercury. By providing adequate heating arrangements, it is possible to produce caustic of strengths greater than 50% with this type, but the two-stage decomposer mentioned later is considered to be preferable for this duty. An interesting variation of the single-stage tower decomposer has been suggested in which perforated graphite plates are used

instead of graphite lumps, and it is claimed that such an arrangement gives a graphite-free caustic solution.

A single-stage tower decomposer flooded with mercury has been developed in the U.S. This decomposer is positioned so that the head of mercury in the tower is sufficient to give gravity flow of denuded mercury back to the electrolyser inlet. The mercury hold-up in this type of decomposer will be appreciably greater than in the conventional type, but the amalgam pumping head is low.

The two-stage type of vertical decomposer is very effective for producing 70 to 73% caustic soda solution. Although the mercury hold-up and pumping head are greater than with the conventional single-stage unit, the two-stage unit has been found to be one of the most successful decomposers developed for production of up to 73% caustic soda solution, and is being used extensively for this purpose.

Mercury v. diaphragm cells

Actual performance and cost comparisons under U.S. conditions have indicated that the overall capital investment and production costs for a plant manufacturing chlorine and concentrated caustic soda are approximately the same for both mercury-cell and diaphragm-cell processes. Considering only the cell house, the capital investment will be higher with mercury cells than with diaphragm cells, mainly because of mercury cost and increased floor space requirement. On the other hand, the expensive caustic evaporation equipment necessary with a diaphragm-cell installation is not required with mercury cells, since a 50 to 70% caustic soda can be produced direct from the decomposer.

With reference to operating costs, a mercury-cell installation requires more labour and a higher degree of skill than a diaphragm-cell installation, and the total power requirement will be about 20% higher. This is compensated for, however, by the fact that steam and water requirements are very much higher with a diaphragm-cell installation, because of the need for caustic evaporation. It follows, therefore, that in many instances the choice between mercury and diaphragm cells depends on the relative costs and availability of power and fuel. Where cheap salt in the form of raw brine is available the diaphragm cell is favoured, since a mercury cell must use solid salt for resaturating the process recycle brine. Combined operation of both diaphragm and mercury cells, the latter using the recovered salt from the caustic evaporators, can be a particularly favourable combination where raw brine is available.

Concerning chlorine quality, there is little to choose between the two types of cell, although hydrogen content of the chlorine from mercury cells will be somewhat higher. Where high-quality caustic soda is required, the mercury cell has a marked advantage, particularly with regard to chloride, chlorate and sulphate contents. Mercury-cell hydrogen contains traces of mercury, but these are fairly easily removed if necessary for subsequent processing.

Future developments

Further development of mercury cells in the future will probably take place with a view to reducing capital investment and operating costs, and utilising the sodium amalgam for purposes other than the manufacture of caustic soda. Capital investment can be reduced by increasing the amperage to floor space ratio, and operating cost economies can be achieved by improving current and energy efficiencies and reducing maintenance charges.

The design of larger amperage mercury cells requiring a minimum of floor space is under active development, and it is of interest to note that 50,000-amp. cells are already in operation and design of a 100,000-amp. cell is under consideration. It is also significant that consideration is being given to the arrangement of horizontal mercury cells in vertical banks to reduce the floor space requirements. Cathodes requiring less mercury would further reduce capital investment, and in this connection vertical mercury cells appear to be the most promising. They already have a high amperage to floor space ratio, and further development of these cells may improve their performance to a point where they will replace the more cumbersome horizontal cells.

The biggest improvement in cell design is likely to come from modification to the electrodes, particularly the anodes, since the anode current density is the determining factor with respect to capacity and energy efficiency of mercury cells. With the development of larger cells, current densities will increase and this will mean more frequent adjustment of anodes. The prime requirement is for more durable anodes which can be replaced as they wear, and it is certain that improved methods of adjusting anodes are being developed.

Further investigation of constructional materials for mercury cells is likely, and it is possible that plastics may replace both rubber and stone linings. The utilisation of the energy available in amalgam decomposers may in the future be found to be a more practicable proposition and, if successful, would reduce operating costs.

Considerable development work has already been carried out on the utilisation of mercury-cell amalgams as an intermediate for manufacturing other products. With continued increasing demand for chlorine production it is possible that the market for caustic soda may reach saturation, and methods of manufacturing chlorine without caustic soda will become increasingly important. To conclude, therefore, it is reasonable to presume that the use of mercury amalgams as intermediates for manufacture of other products is likely to place the mercury cell in a favourable position as a future chlorine producer.

Recent publications

Climbing-film evaporators. In 1830, when considering evaporators for sugars one of the great French authorities, Dubrunfaut, gave his definition of an ideal evaporator, as follows: 'Concentrate the juice as rapidly as possible so as to avoid any alteration. Give the liquor to be evaporated great speed and, if possible, accelerate the movement of the liquor so as to evaporate in the form of a thin film.'

This conception remained a theoretical one until 1899, when Paul Kestner first patented the climbing-film evaporator after many years of research into the behaviour of liquids when being evaporated. He discovered that, when liquor is fed at or near its boiling point into the bottom of a steam-heated tube, evaporation begins, with the consequent release of vapour. This vapour, on account of its very much greater volume, begins to travel up through the tube at a higher velocity than would the liquor. The vapour carries liquor with it and, by suitable design, it is possible to arrange for the liquor to be carried by the vapour through the tube in the form of a thin film travelling along the inside wall of the tube. Moreover, it is not necessary to feed the liquor under a head equivalent to the total height of the tube; it suffices to deliver the liquor to the tube under a head of only a few feet. Hence the name, climbing-film evaporator.

This is one of the points explained in a 12-page illustrated booklet published by Kestner Evaporator & Engineering Co. Ltd. Basic principles of design and operation of climbing-film evaporators are given, as well as details of other types of film evaporators supplied by the company, such as climbing and falling, falling film, and horizontal film designs.

Diesel engine cooling. In the field of oil-engine design great strides have been made and skills developed regarding the construction of the engine itself. Progress in developing ancillary equipment has, however, sometimes lagged behind. This is especially true in the matter of providing cooling facilities for such engines where, even today, practices are indulged in which are positively harmful to the engine operation.

Head Wrightson Processes Ltd. have published, in pamphlet form, an illustrated article by M. E. O'K. Trowbridge and A. J. Hayter which considers the problem of engine cooling and reviews the methods by which waste heat can be dissipated under the various conditions in which oil engines are situated. Diagrams, graphs and tables illustrate the factors involved in the design of a cooling system, and the merits and demerits of various cooling methods are discussed, including lubricating oil cooling, open-circuit cooling by surface water and closed-circuit cooling. Finally the article reviews the various types of cooling apparatus in use, both in Europe and the U.S.

CARBON AND GRAPHITE FOR CHEMICAL PLANT

By A. W. Morrison, B.Sc., B. W. Freedman, B.Eng., and P. G. R. Haines, A.M.I.Chem.E.

(Powell Duffryn Carbon Products Ltd.)

In this paper the authors discuss their subject in three parts. Firstly they describe the manufacture and properties of carbon and graphite. Secondly they describe equipment made of these materials which is now available, for example heat exchangers, packed towers, pumps and ejectors. Thirdly they show how this equipment is being used for special duties in a wide range of chemical industries, owing chiefly to the corrosion resistance of carbon and graphite.

CARBON and graphite are both black and both made from the same raw materials, yet they are quite different in many of their properties. Basically, carbon is made by firing raw materials to 1,000°C.; if further heated in excess of 2,000°C. the carbon is converted to the graphite form. This conversion radically changes many physical properties without affecting the corrosion resistance, so that we now have two different materials which can be incorporated into various plant. Quite often the names carbon and graphite are used loosely; the generic name carbon describes the industry and products as a whole, but the specific words carbon or graphite are used to indicate the applications of these materials in this paper.

MANUFACTURE OF CARBON AND GRAPHITE

The traditional method of making carbon is over 100 years old, and consists of mixing a powdered carbon (petroleum coke is the most common) with a carbonaceous material (tar or pitch) which yields carbon readily on heating. The materials are finely ground, mixed and then moulded to shape by pressing or extrusion. The 'green' article is fired to about 1,000°C. Owing to the difficulty of firing complicated shapes of the material, only simple shapes are moulded and all further work is done by machining on the final product. The carbon so produced is a hard, brittle substance with reasonably low electrical and thermal conductivity.

Graphite is produced by heating carbon in an electric resistance furnace, the conversion taking place at about 1,800°C. and being substantially complete at 3,000°C. This transformation is accompanied by a considerable increase in electrical and thermal conductivity and a considerable decrease in mechanical strength, and a material results which has acquired the characteristic greasy texture of natural graphite. Practically pure electro-graphite can be made by this method, but for general purposes it is usual to carry out graphitisation at a lower temperature, about 2,600°C., when a stronger product is produced without seriously impairing the thermal properties.

A recent British development designed to give a material of close and more uniform texture for chemical plant is the so-called *Delanium* carbon, which is made by moulding powdered coking coal containing a certain amount of swell inhibitor. Both the *Delanium* carbon and graphite materials are extremely dense, uniform and mechanically strong.[1]

Impregnation

By any of the above processes, it has not been found possible to make a material that is completely impermeable; carbon and graphite stocks always have a certain degree of porosity—on an average 20%. For some applications this is not important, but for the majority of chemical plant an impermeable material is necessary. Impermeability is normally obtained on the finished article by an impregnation process using a liquid resin filler, which is then polymerised by heat treatment. Considerable advances have been made in developing new synthetic resins in order that the corrosion resistance and temperature range should be practically the same as for the unimpregnated material. Several different resins have been investigated, but those most widely used at present are based on furfural, phenolic or natural resins such as cashew. Each of these resins has its own particular advantages, for example cashew resin has a higher resistance to oxidising acids than the other two types, but with solvents its resistance is much more limited. The correct type of resin must, therefore, be selected for each application. Other types of impregnation fillings comprise silicones, metals and even carbon. The last material requires careful firing, since the pores of carbon and graphite are filled with the organic material to be carbonised and then the mass is slowly baked to its carbonising temperature. However, it can be stated that impregnants are available which will resist most acids, alkalis or solvents, and are most definitely stable at least up to a temperature of 180°C.

Properties

Carbon and graphite offer to the chemical engineer a pattern of properties that is most unique, and graphite particularly fills the wide gap in properties between the metals and non-metals. Table 1 illustrates the physical properties of carbon and graphite materials. The marked difference in properties between the carbon and graphite is to be noted.

Graphite is highly resistant to thermal shock, a property of considerable importance in chemical plant. This is due to a combination of its low coefficient of thermal expansion—a general figure being 2.5×10^{-6}, which is a third that of steel—and also to its high thermal conductivity.

Perhaps the most outstanding properties of graphite are its high thermal and electrical conductivities. Fully-graphitised carbon has a thermal conductivity of 75 to 80 B.Th.U./hr.sq.ft.°F.ft. at 3,000°C., but in order to produce a material of better strength and hardness properties, a graphit-

PROPERTIES OF DELANIUM MATERIALS

PROPERTY	DELANIUM CARBON	DELANIUM GRAPHITE
DENSITY	1·51	1·67
SPECIFIC ELECTRICAL RESISTANCE OHMS/IN.^{3}	0·0030	0·0009
THERMAL CONDUCTIVITY B.T.H.U./FT.^{2}/HR/°F/FT.	3	40
COMPRESSIVE STRENGTH LBS/IN.^{2}	20,000	15,000
SCLEROSCOPE HARDNESS (SHORE)	65	55
COEFFICIENT OF THERMAL EXPANSION	3.8×10^{-6}/°C.	3.8×10^{-6}/°C.
TRANSVERSE BREAKING STRESS LBS/IN.^{2}	5,000	6,000
ASH%	27	2·4

Table I.

ising temperature of about 2,600°C. is usually used. The thermal conductivity figure under these conditions is of the order of 60 to 75 B.Th.U./hr.sq.ft.°F.ft. When this property is compared with other materials of construction it will be seen that aluminium and copper, the noble metals and their alloys are higher, whereas mild steel (25), lead (18), stainless steel (12), glass and stoneware (1 to 2) are definitely inferior. The electrical conductivity varies as thermal conductivity and for process control it is often taken as a measure of thermal conductivity. The figure normally adopted for the design of graphite electrodes and anodes is 0.0007/ohm/cu.in. Thus, remembering the corrosion resistance of graphite, the high thermal conductivity makes it a unique material for heat-transfer equipment, whilst its high electrical conductivity makes it useful for electrodes and anodes of all types.

Both carbon and graphite can be easily machined to engineering tolerances, carbon requiring tungsten carbide or diamond-tipped tools, whilst graphite, a much softer material, can be machined by normal methods. The compressive strengths, for instance 20,000 lb./sq.in. in the case of carbon and 15,000 lb./sq.in. in the case of graphite, are much higher than their respective tensile strengths, and it is important that the designer should have an appreciation of both the advantageous and limiting physical properties of these materials.

The resistance to most chemical reagents is interesting; only strong oxidising agents such as oleum, chromic acid, concentrated nitric acid and the halogens attack it. It is one of the few materials resistant to aqueous hydrochloric acid, hydrofluoric acid and phosphoric acid at all temperatures. Sulphuric acid concentrations of up to 75% at temperatures of 120°C. can be handled quite easily. Table 2 shows a corrosion chart of the resistance of graphite to various sulphuric acid concentrations. It is noteworthy that the resistance to most alkalis is also high, so that carbon equipment is extremely flexible for use in the chemical industry. The chemical cleaning of this equipment using many of the above reagents is quite a common procedure in industry.

Apart from its corrosion resistance, carbon has the advantage that it will not contaminate solutions and, because of this, it is finding many applications in the pharmaceutical and food industries.

In an inert atmosphere carbon is stable to about 2,000°C. until graphitisation takes place, the graphite itself being stable up to 3,000°C. In the presence of air, however, oxidation starts taking place with carbon at about 350°C., and with graphite somewhat higher. With impregnated material, which is used in plant construction, the resin must be taken into account where temperature and corrosion resistances are concerned; the upper temperature limitation varies between 180 and 250°C., dependent upon the resin. For low-temperature work there is little experimental data available, but –40°F. is quite satisfactory for graphite equipment.

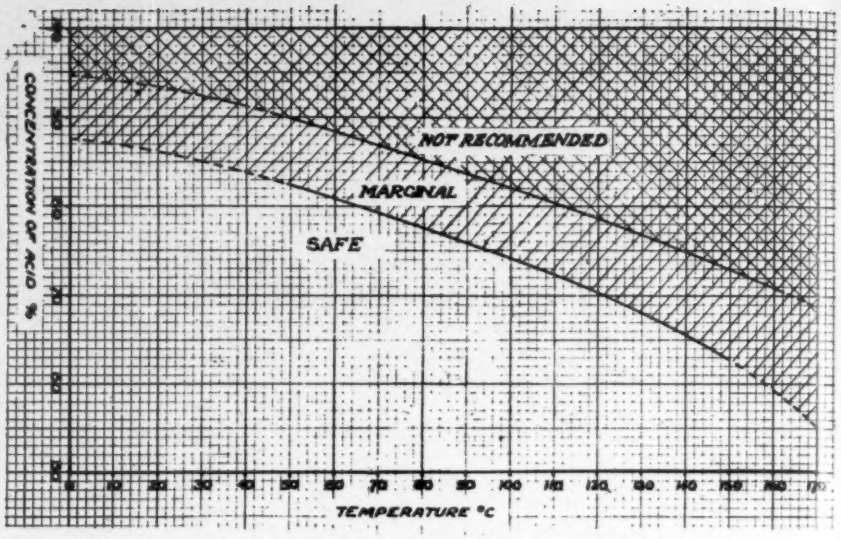

Table 2. Corrosion resistance of graphite in contact with sulphuric acid at varying strengths.

EQUIPMENT IN CARBON AND GRAPHITE

The pioneers of carbon and graphite chemical plant were the National Carbon Corporation of America, who started about 25 years ago. This company held a prominent position in the carbon and electrode fields so that, as suitable synthetic resins appeared, no time was lost in developing an impermeable carbon and graphite. Considerable interest resulted and between the two wars *Karbate* became a well-known trade mark throughout Europe as well as in the U.S. Particularly for heat-transfer equipment graphite soon had its place with other materials such as lead, glass, ceramics, stainless steel, etc. In Great Britain, industrial use has since proved its value to industry and, in the period since the last war, great advances have been made by manufacturers in plant design and fabrication with the development of representative types of process equipment.

In the design of carbon equipment the physical properties of the material should be appreciated by the customer. As mentioned previously, the compressive strength of graphite is far higher than its tensile strength, and the most robust designs are based upon this principle. Since it has a low modulus of elasticity, it will take up a certain amount of deformation, but great care should be taken when lining up carbon equipment, particularly in conjunction with other materials. Carbon and graphite apparatus can very easily be used together with other equipment made of glass, plastic and metals. It is, of course, not malleable like metals and must be adequately protected against mechanical shock. As a material of construction that lies between metals and non-metals, carbon has a design technique of its own which must take into account its limitations as well as its advantages.

Heat-transfer equipment

Obviously the unusual combination of chemical inertness and high thermal conductivity make graphite an ideal material for the fabrication of heat-transfer plant for corrosive fluids. Many different types have been manufactured and, during the past few years, emphasis has been placed on the production of more robust designs and, in these developments, British industry has taken a leading part.

A conventional shell and tube design is illustrated in Fig. 1. This shows a standard *Karbate* unit. The most common construction uses graphite-tube bundles mounted in a steel shell, although, where operating conditions require corrosion-resistant material for both fluids, the shells can be fabricated in carbon or lined with lead, rubber, etc. To overcome differential expansion between the tube bundle and shell, the 'floating head' construction is commonly used, which leaves one tube plate free to move whilst the other is fixed. Some manufacturers prefer a method in which each individual tube is allowed to move relative to the tube plate by insertion of rubber or synthetic rubber ferrules as a flexible joint.[2]

The cubic heat exchanger introduced more recently[3, 4] is shown in Fig. 2. This shows a unit of 50-sq.ft. heat-transfer area. It is constructed from a series of accurately-machined grooved and slotted plates, which are placed under heavy compression by cast-iron clamping plates. The headers fitted to the faces of the graphite block are partitioned to give different pass arrangements and can be fabricated in cast iron, lined with either rubber, carbon or lead.

It is possible to build heat-exchanger systems with total surface areas ranging from a few square feet to hundreds of

square feet by suitably grouping these units together with interconnectors. For standard units operating pressures up to 100 p.s.i.g. can be used and, with specially reinforced header construction, higher pressures may be accommodated.[5]

Both the above types can be used as normal liquid-liquid or gas-liquid heat exchangers, as condensers or as evaporators.

The cascade cooler consists of a vertical bank of graphite tubes cemented at each end into block-type return bands and held together by steel tie rod assemblies. A distributor serves to give a uniform distribution of the liquid over the tubes.

Other heat-transfer equipment used in industry includes the plate, bayonet and coil type of heaters which are normally used for direct immersion in tanks.

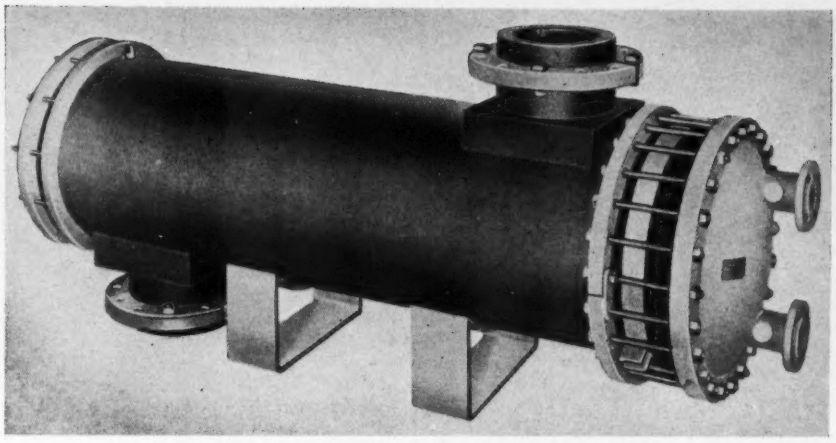

Fig. 1 'Karbate' graphite tube and shell heat exchanger.

Packed towers

Carbon is ideal for the fabrication of packed towers, suitable for absorption, distillation, cooling or scrubbing of corrosive gases. In the United States, where there has been a longer experience in carbon, units have been in operation for a considerable time, one hydrochloric acid tower having been running over 15 years without showing corrosive attack.

Towers first produced were circular in section, being machined from solid graphite electrodes, where, of course, size limitation occurred. A more recent construction is that fabricated from carbon plates and is square or polygon in cross-section.

Complete towers are assembled by bolting together individual sections which may be 3-ft. high. A flange or tie-rod construction is used with suitable gaskets between the sections.

The tower-packing employed includes Raschig rings and grid-type packing. Fig. 3 shows a section of patented *Paragrid* packing, used extensively because of its advantages of uniform liquid distribution and minimum wetting rates, low pressure drop and high gas velocities, thus reducing the overall size of the tower.[6] There is no limit to the maximum size of this type of packing and one cooling tower has packing 16 ft. × 16 ft. × 7 ft. high and is, so far as is known, the largest carbon-packed tower in the world.

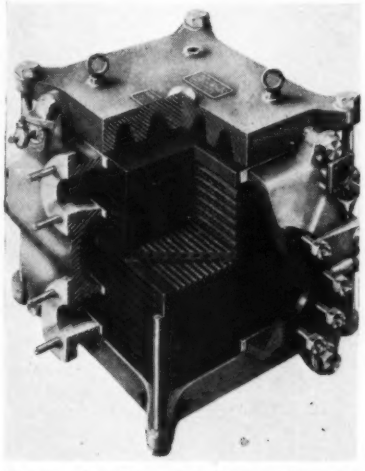

Fig. 2. Graphite cubic heat exchanger.

For applications where large amounts of heat are to be removed, such as in the absorption of the halogen acid gases, sections packed with horizontal graphite tubes are incorporated with specially designed headers clamped to the walls of the tower for introduction of the cooling medium. A unit of this type is described in more detail later.

Carbon pumps

Owing to the increasing importance of providing means for transporting hot corrosive fluids, the carbon pump cannot be overlooked. When the first pumps were manufactured several years ago industrialists had their doubts, but operational experience has shown the suitability of carbon for pump construction. Normal body and impeller designs are employed and graphite carbon glands can be used with advantage as seals.

Other equipment

Multistage ejectors fabricated in carbon are finding increasing importance in vacuum equipment for handling corrosive vapours. Injectors are used for introducing steam or other fluids into solutions where an efficient means of agitation and heating are required. Sulphuric acid dilution plants which incorporate a carbon mixer for the strong acid and water flows plus a suitable carbon heat exchanger are becoming popular.

It has been mentioned that carbon is porous; this property can be controlled and porous carbon filters are made. An interesting application is the adoption of the cubic design based on the heat exchanger, but using unimpregnated carbon instead of impregnated graphite for a high-pressure filter system.

Thermometer sheaths of graphite are used for corrosive conditions where the temperature variations call for an immediate control response.

Carbon is, of course, an excellent material for tile lining of vessels containing corrosive liquors where abrasion is met.

It is used in large quantities as electrodes in the manufacture of steel, aluminium, phosphorus, chlorine, caustic soda and the like.

The use of graphite moulds for the casting of ferrous and non-ferrous metals is of interest, due both to the exceptional finish of the articles and the life of the moulds.

INDUSTRIAL APPLICATIONS

Carbon and graphite have many uses in the general industrial field, but particular reference must be made to the chemical industry, where severe corrosive conditions are often encountered. For these applications, other corrosion-resistant materials such as lead, glass, stoneware, rubber and stainless steel are employed, but obviously the better general corrosion-resistant qualities of graphite, coupled with its high thermal conductivity, make it an ideal material for many industrial problems. Carbon and graphite are replacing lead for many heat-exchange problems, particularly where sulphuric acid and salts are used. It is impossible to cover all the applications, but brief mention should be made of installations that are operating satisfactorily with carbon and graphite equipment.

In the **chemical industry** as heat exchangers, absorption towers, thermometer sheaths, tank linings and filters. All types of inorganic and organic acids, alkalis and chlorinated organic compounds are being handled.

In the **synthetic fibre industry** as heat exchanger and evaporator equipment.

For the heating and maintenance of temperature of **plating and pickling baths** where the corrosive fluid may be nickel sulphate solution, a dilute solution of sulphuric acid or hydrochloric acid.[7]

In the **steel industry** for the recovery of sulphuric acid from waste pickle liquor.

In the **fertiliser industry** for the heating and evaporation of phosphoric acid, for heating sulphuric acid and for the recovery of fluorides.

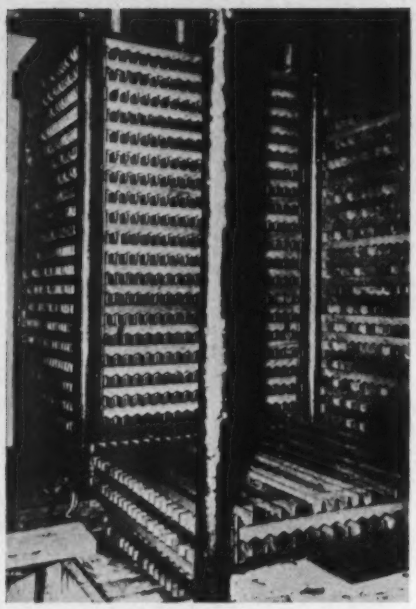

Fig. 3. Carbon 'Paragrid' packing in course of erection.

In the manufacture of **pharmaceuticals** as condensing plant for corrosive organic vapours, as evaporators and as heat exchangers.

In the **food industry** for the concentration of protein liquors and fruit juices.

As a **heat recovery unit** for waste gases and liquors which are corrosive.

For the construction of **absorption and distillation** plant, where particular reference may be made to hydrochloric acid, hydrogen bromide and hydrogen fluoride.

For the **pumping** of corrosive fluids.

For the lining of vessels subject to reactions of a corrosive nature, *e.g.* in the **wood pulp industry** and particularly where fluorides are present.

In the **electro-chemical industry** for the provision of electrodes.

A new field is **cathodic protection of metals**, for example by inserting graphite electrodes into headers of metallic heat exchangers handling sea water, or for anodes for the protection of buried pipelines and steel structures.[8]

The above are only a few of the applications which are today increasing considerably with the ever-expanding field of chemistry.

Industrial overall heat-transfer coefficients

Fig. 4 shows a typical curve obtained for overall coefficient *v.* liquid velocity. In this particular case, steam and water are the fluids in question.

Table 3 shows the kind of overall coefficients obtained in practice in industry for a variety of applications, *i.e.* heating, condensing and evaporation coefficients, where the cubic heat exchanger is employed.

In the section devoted to gas cooling coefficients, the hydrochloric acid, air and water vapour mixture refers to a typical gas composition from a continuous salt-cake furnace.

The condensing coefficient for the ammonia/carbon dioxide mixture was obtained using the cubic heat exchanger as a reflux condenser in an ammoniacal liquor recovery plant.

Typical problems

(*a*) **Evaporation plant.** A typical climbing-film type of evaporation plant, consisting of preheater and evaporator block, can be easily adapted to operate on thermal or forced circulation, depending upon the specific application. One plant was used for conducting a series of experiments on water evaporation at atmospheric pressure. Feed rates up to 500 gal./hr. were used and the inlet temperature to the evaporator was maintained at approximately 100°C., in order that true boiling coefficients could be obtained. Steam pressures were varied from 10 to 50 p.s.i. and, by cutting off the supply of steam to individual blocks, the effect of $\frac{L}{D}$ ratio was investigated. Overall heat-transfer coefficients up to 600 C.H.U./hr.sq.ft.°C. were obtained during these experiments.

(*b*) **Condensations of organics.** Fig. 5 shows a typical installation of a heat exchanger of the cubic type for condensing organic vapours. The vapour in question is a chlorinated alcohol.

(*c*) **Plant for the evaporation and recovery of hydrochloric acid.** In the manufacture of certain synthetic food

INDUSTRIAL OVERALL HEAT TRANSFER COEFFICIENTS

(ATMOSPHERIC PRESSURE)
OBTAINED WITH THE POWELL DUFFRYN CUBIC HEAT EXCHANGER

1. STEAM HEATING

LIQUOR	VELOCITY FT./SEC.	MEAN TEMPERATURE °C.	U C.H.U./HR/FT.²/°C.
WATER OR WEAK LIQUORS	4	50	400-500
10% SULPHURIC ACID + 23% SODIUM SULPHATE	6	50	300-350
50% SULPHURIC ACID	4	50	200-250
30% HYDROCHLORIC ACID	4	40	300-350
85% PHOSPHORIC ACID	4	50	150-200

2. BRINE COOLING

10% HYDROCHLORIC ACID	4	60	200-250
15% CAUSTIC SODA	4	50	150-200

3. GAS COOLING

GAS	MEAN VELOCITY FT./SEC.	MEAN TEMPERATURE °C.	U C.H.U./HR/FT.²/°C
AIR	50	40	14
30% HCL + 70% AIR + TRACE WATER VAPOUR	45	110	25

4. EVAPORATION

LIQUID	EVAPORATION RATE LB/FT.²HT.SURFACE/HR	MEAN TEMPERATURE °C.	U C.H.U./HR/FT.²/°C
WATER OR WEAK LIQUORS	40	100	450-650
35%-60% SULPHURIC ACID	14	110-140	200-250
50%-65% SULPHURIC ACID	5	120-145	140-200
CONCENTRATED FRUIT JUICE	12	105	150-200

5. CONDENSATION (INCLUDING SUBCOOLING)

VAPOUR	CONDENSATION RATE LB/FT.²HT.SURFACE/HR	MEAN TEMPERATURE °C	U C.H.U./HR/FT.²/°C
WATER OR WEAK MIXTURES	60-70	100	400-500
METHYL ALCOHOL	20	65	150-200
ETHYLENE DICHLORIDE (ACID CONTAMINATED)	20-40	83	100-150
17% NH_3 + 8% CO_2 + 2% H_2S + 73% H_2O	35	93	100

Table 3.

extracts the raw materials, such as corn or maize gluten, must be hydrolysed to recover the valuable protein matter. This hydrolysis is usually carried out by digesting with hydrochloric acid, the liquor then being neutralised and concentrated to the final products. An intermediate stage in this process, which is necessary in order to reduce the salt content of the product, is to evaporate off a certain amount of the hydrochloric acid, which is then recovered and re-used in the hydrolysis reactions.

The type of plant installed will depend on the concentration of HCl in the feed liquor. If this is much below the constant boiling mixture, *i.e.* approximately 20%, then distillation is necessary to recover the acid in a usable strength. If above this concentration, then a column is not required, as the distillate will be fairly strong.

Fig. 6 shows an installation sub-divided into two separate plants, one to handle liquor of weak HCl content and the other for strong HCl content. The illustration shows the type of carbon and graphite equipment that has been designed and manufactured for the project. The plant handling the strong HCl liquor is in the foreground and the weak HCl plant is in the background.

This figure shows clearly the evaporators consisting of vertical banks of cubic heat exchangers operating under 'once-through' flow for the liquor. The vapour liquid mixture leaves the top of the evaporator and passes to an impact separator constructed with carbon baffle plates and a glass container. The liquid separated is the concentrated product, which is cooled and then passes forward for further processing. In the case of the strong HCl feed, the vapour passes direct to a surface condenser which is seen on the left-hand side of the photograph and then goes *via* the HCl cooler to storage.

For the weak HCl feed, the vapour passes to the distillation column (1 ft. × 1ft. with 12 ft. *Paragrid* packing). The base of the distillation column can be seen in the middle of the photograph. The distillation column concentrates the weak HCl vapour to produce 17% HCl acid from the bottom. The total capacity

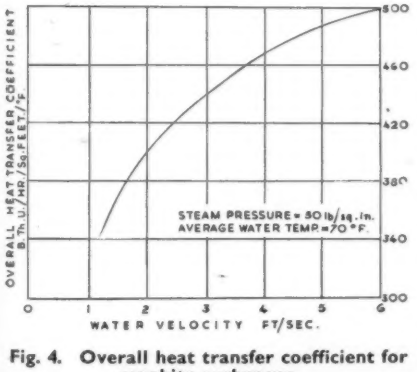

Fig. 4. Overall heat transfer coefficient for graphite exchanger.

of the two plants is 300 gal./hr., *i.e.* 40 tons/day.

Steam at 75 p.s.i.g. is used throughout and cooling water at 30°C. The plant is adequately instrumented in order to provide satisfactory operation. This includes temperatures, pressure and flow measurements at certain points in the plant, and specific gravity meters installed for control of products.

(*d*) **Hydrochloric acid absorption plant.** Graphite is one of the few materials of construction suitable for handling hydrochloric acid solutions, others being fused silica, glass and tantalum.

Several courses are available for the production of hydrogen chloride, the most common being combustion of chlorine in hydrogen (synthetic process); as a by-product in the chlorination of organic compounds; and by the action of sulphuric acid on common salt or potassium chloride (salt cake process).

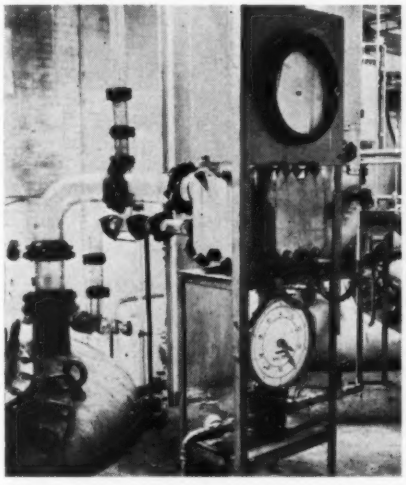

Fig. 5. Graphite exchanger for condensing acid-contaminated vapours in a fine chemical factory.

Graphite equipment installed in a factory using the latter process is described below.

Fig. 7 shows a section of the absorption tower, 30 in. in cross-section × 24 ft. high. The tower consists of six graphite cooling tube sections, the top distribution and bottom sections. This tower will produce 180 to 200 tons/day of 21°Be (34%) acid from a gas containing 30 to 40% v./v. hydrogen chloride, entering at about 55°C. No recirculation is necessary, as the make-up water necessary is sufficient adequately to wet the packing. Due to the sulphuric mist problem which usually accompanies the salt cake process, a final venturi scrubber system is incorporated in the plant layout.

Cubic heat exchangers are installed for the primary cooling of the furnace gases from 180°C. to entry into the absorber at 55°C., replacing very large ceramic tube coolers. In the gas cooler, first installed for experimental purposes, the hot gas enters at the top, passes through the

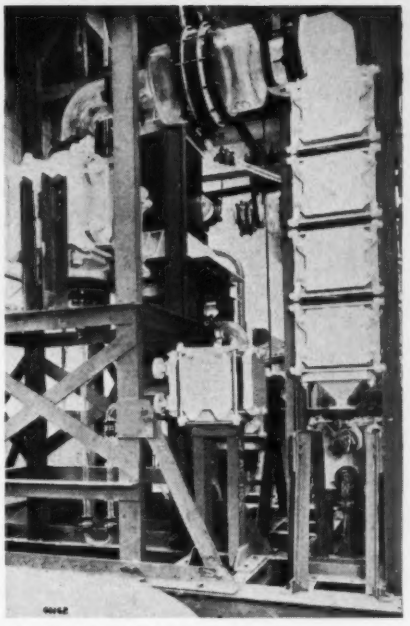

Fig. 6. Graphite evaporator, separator and condenser unit for recovery of hydrochloric acid.

water-cooled heat exchanger, and thence to the main absorption plant *via* a large vertical pipe.

Risk of scaling or blockage in the tubes of the heat exchanger is eliminated by the introduction of a fine liquor spray at the inlet header. A permanent spray was later installed.

A further development has been made in building complete hydrochloric acid absorption equipment based upon the cubic heat exchanger design, and Fig. 8 shows a diagrammatic illustration of a plant capable of producing 40 tons/day of 21°Be acid from 30% (v./v.) hydrogen chloride gas. The gas cooler (a 50-sq.ft. unit) is shown on the right of the diagram. The cooled gas then enters the absorber, consisting of a bank of cubic heat exchangers (150 sq. ft.) arranged vertically in series. The gas flows concurrently with the liquid through each unit. For maintaining efficient mixing of liquid and vapour and good distribution over the face of the exchanger, the inlet headers have been enlarged. These distributing boxes, as they are called, may be fabricated in synthetic resin, carbon or rubber-lined steel. Circulation of the acid is also employed over the lower tube units to allow for variations in gas strength and quantity. The diagram also shows the final venturi scrubber and separator, if required, before passing the gas to the stack.

Summary

Carbon and graphite are now recognised as materials of construction for chemical plant owing to the considerable use to which they have been put in the post-war years. Their value as useful items of

Fig. 7. Section of hydrochloric acid absorption tower.

capital equipment rests on their corrosion-resistant properties and the good heat-transfer qualities of graphite. British manufacturers are taking a leading part in this advance, and Britain can pride herself on the fact that many of the newest designs in this field have been so rapidly developed within a short time of their inception in this country that, for instance, hundreds of cubic heat exchanger units have been installed throughout the world. As an instance of what can be achieved, the graphite cubic heat exchanger has been accepted by leading American firms and these units are now being manufactured in the U.S.

The matter does not rest there, for new designs now under development will increase the scope for chemical plant.

Carbon therefore has arrived to take its place alongside the traditional materials of construction as a useful ally in a wide range of industry.

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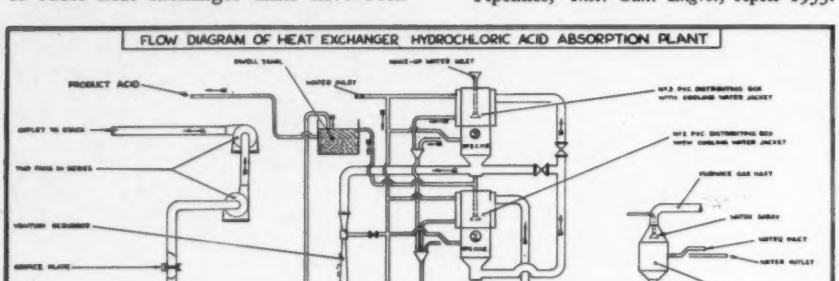

Fig. 8. Plant for producing 40 tons/day of 21° Be hydrochloric acid from 30% (v/v) hydrogen chloride gas.

Low-cost handling of cement raw materials

The economic production of cement depends upon continual supply of raw materials at low transport cost. A good example of low-cost transport is the Hope (North Derbyshire) works of G. & T. Earle Ltd. This cement works is one of the largest in Britain, and extensions to meet the growing demand are raising the output by over 3,000 tons/week. The extensions to the handling plant, described in a recent issue of *Mechanical Handling*, include a large gyratory crusher and an installation of Mavor & Coulson sectional belt conveyors.

A new crusher house has been built so that its topmost storey is on a level with the floor of a new limestone quarry and its lowest storey is on a level with the floor of the old quarry, which will become obsolete. The new face is about 500 ft. long and 45 ft. high. Drilling is continuous. A moderate amount of shotfiring breaks up the limestone, which is then shovelled by bucket diggers into rubber-tyred dumpers of 9 cu. yd. capacity, holding about 12 tons each. There are seven of these and they deliver over a ramp to the top storey of the crusher house, which contains the gyratory crusher. To ensure that the stone is clean and of good quality for cement making, all the quarry product passes through a series of feeders, screens or grizzlies before being fed to the crushing bowl. The crusher, weighing 300 tons and driven by a 400-h.p. motor, can deal with over 500 tons/hr. of stone, crushing it to lumps passing a 6-in. ring.

The screened and crushed stone is carried on the first of three 42-in. conveyors over a continuous weighing machine, which shows the actual rate of flow at the moment and records the total tonnage carried. The first conveyor is only 98 ft. long, but the second is 700 ft. and the third 325 ft. long.

Tension is applied to the second conveyor belt in a way that is unusual on the surface. Since the belt is so long, the tension pulley needs to have a travel of many feet to take up the slack. The tail pulley could not move far without coming against the concrete wall of the house, while the head pulley cannot be moved without complicating the delivery to the next conveyor. There is no height for a gravity take-up without excavating a pit to accommodate it—a costly proceeding in this instance. A loop take-up is therefore placed below the conveyor, near the delivery end. It consists of two pulleys round which the belt passes in an 'S' and a rope winch for drawing one of the pulleys along guides. In this way, 18 ft. of travel is provided. The take-up stands where the belt comes out of the driving gear; that is the point where on a level conveyor any slack belt would tend to gather, and where tension can be applied most easily.

The third conveyor carries the stone on to the old crusher house overlooking the cement works. From here the stone travels downhill on a further 600 ft. of conveyors, through more crushing plant, to the final grinding mills. At an intermediate point the stone is diverted, from time to time, to a conveyor that runs in the open, almost level, to form a large stockpile. The stocks can be reclaimed by a navvy, which empties into a hopper over the lower end of an elevating conveyor. This returns the stone to the main conveyor line for transport to the works.

Ingenious use is made of tubular scaffolding for carrying both the stocking and the reclaiming conveyor, this enabling them to be quickly erected just where required by two men who had no previous knowledge of conveyors.

The stockpile is large enough to keep the works going if the new crushing plant ever had to be closed down for several days. Any small shortage of stone supply is met nearer the works from a stocking building, in which stone is put into stocks by a tripper on the conveyor line and returned to the line by a bucket elevator.

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Chemical Engineering Research at the Massachusetts Institute of Technology

Brief details of research in chemical engineering carried out to obtain the Doctor's Degree at the Massachusetts Institute of Technology are given in the latest edition of 'Abstracts of Theses'* published by the Institute. Below we give abstracts of six theses prepared in the Department of Chemical Engineering and abstracts of four other theses of chemical engineering interest but prepared in other departments.

Rate of ion exchange

R. F. Baddour

THE rate of the exchange of sodium and hydrogen ions between solution and resin phases was studied, using as an ion exchange resin *Dowex* 50, which is essentially sulphonated polystyrene.

The exchange was performed by passing sodium chloride or hydrochloric acid solutions through packed beds of carefully sized, spherical particles of *Dowex* 50. The variables studied were particle diameter, solution flow rate, solution concentration and bed dimensions.

The results show that the assumption of a rate of exchange limited by the rate of mass transfer permits the development of a rate equation that adequately correlates the data for the different variables and permits the prediction of results, in terms of fundamental properties of the resin and of the solution, to be obtained for conditions for which no data are available.

The technique used here for ion exchange has been successfully applied to exchange absorption systems and, theoretically, should be applicable to other similar systems. Also, the results should be applicable under proper conditions to a moving-bed system, and the equation for such a system has been developed.

Thesis supervisor: Edwin R. Gilliland, Professor of Chemical Engineering.

Carbon-steam system at low temperatures and under pressure

H. G. Hipkin

Wood charcoal and Disco coke, mixed with potassium carbonate, have been gasified with steam at 1,100 to 1,200°F. and from atmospheric pressure to 750 p.s.i. over a wide range of steam rates. The effects of adding carbon monoxide, carbon dioxide, hydrogen and argon to the steam have been noted. A few data were collected for the uncatalysed gasification of wood charcoal with steam at the same temperatures, for comparison. A preliminary batch study of the effect of treating a reactive German brown coal with water at 750°F. and pressures up to 5,500 p.s.i. was made.

The results of the preliminary study showed that the benzene-soluble content of the brown coal could be increased by treatment with water at high pressures. This phenomenon is believed to represent hydration of the volatile constituents of the coal.

The results of the gasification studies are presented as gas compositions and rate data.

The dry gas produced was essentially hydrogen and carbon dioxide. At elevated pressure, appreciable quantities of methane were formed, but addition of potassium carbonate reduced the quantity of methane. The water-gas shift was always substantially at equilibrium.

The carbon gasification rate was increased two- to three-fold by the addition of potassium carbonate, and was increased by increasing steam rate and decreased by increasing pressure. Dilution of the feed with carbon monoxide, hydrogen or carbon dioxide reduced the rate, while dilution with argon increased the rate slightly. The rates at constant temperature were correlated as a function of the outlet partial pressures by an expression of the type,

$$rate = K\left(\frac{p_{H_2O}}{p_{CO_2} \cdot p_{H_2}}\right)^a,$$

where a is a constant between 0.5 and 0.6.

These results have been interpreted as follows: (1) Methane is formed chiefly by a secondary hydrogenation reaction; (2) the primary gasification reaction is poisoned by hydrogen and in the catalysed system is also poisoned by carbon dioxide; (3) carbon dioxide exerts its retarding effect by influencing the catalyst rather than by blocking adsorptive centres on the carbon.

Continuous removal of carbon dioxide from the catalysed system is a process that presents interesting potentialities for further low-temperature work.

Thesis supervisor: Edwin R. Gilliland, Professor of Chemical Engineering.

Use of sulphur in preparation of adsorptive carbons

A. B. Metzner

This thesis is primarily concerned with the use of elementary sulphur as an oxidant for the selective removal of hydrogen or hydrogen-rich material from carbons produced by pyrolysis of organic matter, the purpose of this treatment being the activation, that is, the enhancement of the adsorptive properties, of these carbons.

The reactions between hardwood charcoal and sulphur vapours have been investigated in a fluidised-bed reactor over the temperature range from 300 to 600°C. The rate of hydrogen sulphide evolution resulting from this treatment has been correlated (over the entire temperature range investigated) by the equation,

$$-\frac{dn}{d\theta} = (k_1\, n^{3.7} + k_2)\, p^{0.28},$$

where $-\frac{dn}{d\theta}$ = rate of hydrogen sulphide evolution, gram-moles per minute,

n = hydrogen content of the solid, gram-moles, at time θ minutes and

p = pressure of the sulphur vapours, millimeters of mercury.

The rate constants, k_1 and k_2, are functions of temperature only. The equation is based on a charge of 150 g. of charcoal.

The optimum temperature for dehydrogenation was found to be about 500°C. A solid carbon-sulphur complex, containing up to about 40% sulphur, formed as a result of treatment at this temperature. Desulphurisation of this complex with hydrogen resulted in the production of a highly adsorptive product. Optimum desulphurisation occurred at a temperature level of about 860°C.

This sulphur-hydrogen activation process produced a much higher yield of less friable product than obtainable by conventional steam-activation of the same raw material. The adsorptive capacity of the latter was, however, somewhat higher.

It was found that a considerable enhancement of the adsorptivity of charcoal may be achieved by treating it with inert gases, such as nitrogen or helium, at elevated temperatures. The presence of small quantities of oxygen in such gases appeared to have an extremely detrimental effect on the quality of the product when exposure to such gases was continued for a long period of time.

Thesis supervisor: Warren K. Lewis, Professor of Chemical Engineering, Emeritus; Lecturer.

Production of pure sulphur dioxide

T. K. Roy

The production of sulphur dioxide from sulphur vapours and FeS using Fe_2O_3

* Dated June 1951 and published Cambridge, Massachusetts, 1952, pp. 156, $2.

(hematite iron ore) as the oxidiser was studied in a fluidised powder system. In all cases the sulphur dioxide was essentially free of oxygen, sulphur and sulphur trioxide. The sulphur vapour was used mixed with either nitrogen or sulphur dioxide as fluidising gas. High rates of reaction were obtained in the temperature region 580 to 850°C. It was found that with feed gases containing from 3 to 22 mol.% sulphur (calculated as S_2) a considerable portion of the sulphur fed (about 10% at the highest temperature and as high as 50% at the lowest temperature) was retained by the solids in the bed. At the higher temperatures, if the sulphur addition was discontinued, the solids would continue to liberate sulphur dioxide until essentially all the sulphur was removed. When most of the Fe_2O_3 had been reduced to Fe_3O_4, the sulphur vapour was still completely consumed, but a much higher percentage of it was retained by the solids.

The runs involving the reaction of iron sulphide with Fe_2O_3 were carried out using sulphur dioxide as fluidising gas. Essentially complete oxidation of the FeS to sulphur dioxide was obtained at temperatures of 800 to 920°C. within 20 to 60 min. The rate of sulphur dioxide production per unit weight of FeS in the bed decreased as the run proceeded, indicating the residual material to be either less reactive or less available for reaction. Oxides of manganese and copper appear to react in a manner similar to Fe_2O_3.

As a result of the studies it is concluded that the metal oxides would be suitable for commercial production of pure sulphur dioxide from sulphur vapour, iron sulphide or pyrites.

Thesis supervisor: Edwin R. Gilliland, Professor of Chemical Engineering.

Use of salt solutions and solid adsorptions to dehyrate gases and organic liquids

C. A. Stokes

This investigation is of a survey nature, exploring: (1) possibilities of new salt solution dehydrating agents for gases and organic liquids and methods for predicting the efficacy of these agents and for relating the vapour pressure of salt solutions to their temperatures and concentrations; and (2) possibilities of using the fluidised-bed process for drying gases with solid adsorbents.

Vapour-pressure-lowering effects have been found to be sufficiently similar among salts of cationic elements of a given periodic group to allow estimation of this property from that of known salts and solubility data, temperature and anion having relatively less effect. Outstanding vapour-pressure-lowering effect has been predicted and checked by experiment for the chlorates and perchlorates of Li, Ca and Cd; potassium formate; lithium thiocyanate and chromate. Salt mixtures offer limitless possibilities, $ZnCl_2$—$CaCl_2$ and potassium formate-acetate mixtures showing 97 and 92% vapour pressure lowering. $ZnBr_2$ solutions have been found promising because of the inhibiting effect on corrosion of mild steel under aerated conditions. Since comparatively dilute (30%) $CaCl_2$ solution has given 19 to 27% lower mass transfer coefficient than pure water in wetted wall tower dehumidification of air, this effect should be investigated for new salts before practical use is attempted.

A new method of measuring moisture content of gases has been devised but not developed for practical use.

The Van Laar equation has been found to correlate salt solution vapour pressure data within $\pm 10\%$ over a limited range of concentration and temperature. A new method that relates activity coefficient of water for a given salt solution to that for a reference salt solution and is more precise over a wider range of temperature and concentration than the Van Laar equation has been developed.

The maximum degree of dehydration of organic liquids by salt solutions has been predicted from readily available data, and these predictions have been checked by experiment.

Practical mass transfer rates were obtained when dehydration was carried out continuously in conventional counter-current extraction apparatus.

The volume rate of mass transfer in fluidised-bed adsorption dehumidification of air has been found to be 15 to 30 times that for a fixed bed and 60 to 120 times that for typical absorption processes. A tentative design method for fluidised-bed adsorbers is recommended. An adsorbent of greatly increased capacity has been made by impregnating a porous adsorbent with a solution of a hygroscopic salt.

Thesis supervisors: Thomas K. Sherwood, Professor of Chemical Engineering; Herman P. Meissner, Professor of Chemical Engineering.

Kinetics of exchange adsorption

F. A. Ryan

This thesis is the latest in a series of Bachelor of Science, Master of Science and Doctor of Science theses dealing with the general problem of the adsorption separation of petroleum hydrocarbon gases. While earlier work has been primarily concerned with equilibrium phenomena, this thesis is a study of the rates of exchange of one gas for another on an adsorbent.

The rates of exchange are presented for a number of gas systems (ethane, ethylene, propane, propylene, isobutane, helium) on silica gel and activated charcoal at various temperatures, pressures, particle sizes and flow rates. The investigation covered fixed-bed and moving-bed experiments. The data are correlated in terms of H.E.T.P.s and mass transfer coefficients based on a single film resistance concept.

Thesis supervisor: Edwin R. Gilliland, Professor of Chemical Engineering.

Biology and biochemistry of the micro-organisms in activated sludge

R. E. McKinney

The object of this study was to isolate some of the floc-producing organisms in the activated sludge process and to study their biochemical relationships in the purification of sewage.

Two techniques were used to isolate the floc-formers, direct aeration and multiple dilutions. The direct aeration process consisted of using miniature aeration tanks to concentrate the floc-formers for subsequent isolation by standard bacteriological procedures. The multiple-transfer method used the principle which had been successful in the isolation of plankton, that of repeated transfer with the desired organism building up until a pure culture was obtained in a liquid medium. These two processes yielded several floc-forming organisms.

After the isolation of these organisms had been made, biochemical tests were set up to identify them. The identification tests used were those set forth by the Society of American Bacteriologists for the identification of bacteria. The bacteria were identified with the aid of Bergy's *Manual of Determinative Bacteriology* (87). The cultures identified in this study inincluded: *Zooglea ramigera*, *Bacillus cereus*, *Escherichia intermedium*, *Paracolobactrum aerogenoides* and *Norcardia actinomorpha*.

Biochemical tests were set up in small aeration units to determine the ability of pure cultures of organism to floc and to remove B.O.D. under conditions similar to activated sludge. Both sterile settled sewage and sterile synthetic sewage were used as substrates. The B.O.D. removals ranged from 5 to 75% in a 24-hr. aeration period. Higher removals were obtained when several pure cultures were mixed than when the pure cultures were aerated alone. The addition of *Paramecium* to the pure culture sludge caused the B.O.D. removals to be increased. The results of these organisms checked favourably against the results obtained by other investigators who worked with pure culture sludges.

The next phase of the study concerned the respiration of the organisms. The Warburg apparatus was used to determine the oxygen uptake and the carbon dioxide production of the pure cultures in suspension and in sludges. Other sewage organisms were studied in an effort to learn of the comparative rates of oxidation. The substrates used in this study included dextrose, peptone and the combination of dextrose and peptone. Continual readings of the oxygen uptake and the carbon dioxide production over a two-day period were made. The oxygen utilisation curves followed the bacterial life-cycle curve, indicating that the rate of oxidation was a function of the number of organisms present. The Respiratory Quotient, a ratio of CO_2: O_2 by volumes, was determined as

a means of learning to what degree the organic material was oxidised. The majority of the organisms were capable of oxidising the organic material to carbon dioxide and water.

The final phase concerned the composition and formation of the sludge proper. Chemical analyses were run on the sludge ash to determine its mineral components. Other analyses were made to learn of the nitrogen distribution in the sludge. The theories of colloidal chemistry were reviewed and combined with previous experiments by other investigators in the field of bacteriology. This information was correlated with known information in the field of sanitary engineering and with knowledge gained through experiments to formulate a theory explaining the production of activated sludge and the operation of treatment plants for sewage and industrial wastes.

Thesis supervisor: Murray P. Horwood, Professor of Sanitary Science.

Hydrodynamics study of valves and orifices

F. F. Ehrich

Flow regulation is accomplished by two successive mechanisms. The fluid passes through an orifice of variable size at the edge of which the main body of fluid separates from the walls and forms a jet which streams into the mixing section. In the mixing section, viscous action dissipates the energy involved in this flow field and establishes stable flow at a lower stagnation pressure. The complex mechanism may be approximated by the mathematical model of discontinuous flow. A flow field is hypothesised with the region of high-velocity gradient approximated by an infinitesimal discontinuity at constant pressure.

In a flow bounded by straight solid walls and such streamlines of discontinuity, the various parameters of pressure and geometry may be solved for by successive transformations involving the physical plane, the complex conjugate hodograph plane, the logarithm of this conjugate hodograph plane, the complex potential plane and an intermediate mapping plane utilising the Schwarz-Christoffel method.

Such an analysis was carried out for a geometry resembling an idealised two-dimensional gate valve. Experimental investigation of the geometry of the flow, the pressures on the walls, the force on the gate and the nature of the stream exiting from the orifice proved that this analysis gave a good quantitative estimate of the variables in question.

Then a similar analysis was made of various simple idealised shapes approximating the flapper valve, the needle valve, the globe valve and the butterfly valve. The size of the exit stream as a function of the valve opening was computed in each case.

Certain approximate considerations allow these two-dimensional results to be applied to the axially symmetric configuration.

Thesis supervisor: John A. Hrones, Professor of Mechanical Engineering.

Flow of air through a cascade

D. C. Prince, Jun.

The subject matter of this thesis divides itself naturally into independent parts. The first part deals with the theoretical design of cascades and with theoretical methods of analysis of performance. The second part describes testing problems and gives test results for a particular cascade. The interpretation of the results and their application to practical design problems are discussed.

The theoretical design of cascades is based on the methods of conformal transformation. With the assumption of plane two-dimensional, incompressible, non-viscous flow, methods are developed for designing cascades of airfoils with desired characteristics. The procedures can be used for closely-spaced compressor cascades and for turbine cascades. In this way compressor cascades can be designed with higher performances than are used in current practice, and turbine cascades may be designed with higher efficiencies and more economical use of materials than is now the case. Slight extensions based on the design method allow the prediction of pressure distributions for all possible upstream flow angles. The information obtained in this way is then used further to analyse the expected growth of boundary layers on the airfoil, so that predictions may be made for performance of the airfoils in a real fluid.

The second part of the report describes the testing of a cascade of airfoils originally designed as an illustration of the methods of the first part. Several problems were encountered that have not previously been mentioned in the literature. It was found that it was difficult to produce uniform flow at an upstream flow angle such as might be expected to produce a stalled condition on the airfoils. The pressure rise obtained under such conditions appeared consistent with pressure rises obtained at other upstream flow angles. At the design flow angle there appeared to be separation of a laminar boundary layer. It was necessary to induce artificial turbulence to obtain satisfactory performance of the cascade.

Tests results include measured pressure distributions and comparisons with the predictions, wake traverses for determination of losses and measured stream deflections. Methods of interpretation include presentation of tangential and normal force coefficients and of lift and drag coefficients and a new method for presenting axial flow compressor stage efficiency in terms of parameters to be found from cascade testing.

Thesis supervisor: William R. Hawthorne, Professor of Mechanical Engineering.

Mechanical properties of metals at liquid helium temperatures

A. S. Eldin

The completion of the large Collins cryostat, which has a large experimental space that can be maintained at any desired level of temperature between room temperature and liquid helium temperature, has provided an excellent facility for the investigation of the mechanical properties of metals in the low-temperature region.

A portable tensile testing machine which is lowered inside the cryostat experimental space has been constructed. The tensile machine has a hydraulic loading system capable of exerting a tension of 60,000 lb. The force is measured by a calibrated load cell in series with the load-transmitting member.

For the measurement of strain an extensometer, which operates in connection with a special micrometer, has been developed.

The object of the investigation undertaken was twofold: first, to measure the tensile properties of metals at liquid-helium temperatures and to determine the occurring changes with low-temperature variation; second, to determine the room-temperature brittle strength of a low-carbon steel from extrapolated measurements at extreme low temperatures.

For a 1020 steel a very definite transition temperature of about 59°K. has been detected. Only 1° *below* that temperature the metal will lose its yield point. *Above* that temperature, the steel can have a yield stress and a breaking stress. Below that temperature the brittle strength shows a tendency to increase with decrease of temperature.

The considerable variation of reduction of area within a very narrow range of temperature is very striking. Further experimentation in the region of very low temperatures is needed to establish firmly the shape of the brittle strength curve.

The performance of the cryostat was contrary to what was anticipated. It developed the characteristic troubles of machines that operate in the region of extreme low temperatures. The leakage of air into the system and its eventual freezing in the expansion engines interfered with the attainment of the hoped-for low temperatures.

The leakage of helium out caused a costly consumption and a shortage of the gas that led to a curtailment of the number of tests.

The cryostat is well on its way to a better operation as more experience is being accumulated concerning the function of its different components at low temperatures, and before long extensive testing will become a possibility. It has been possible to extend the range of measurements to 12°K.

Thesis supervisor: Samuel C. Collins, Professor of Mechanical Engineering.

Penicillin and Streptomycin Production

A substantial part of Britain's output of penicillin, streptomycin and vitamin B_{12} comes from Glaxo Laboratories factory at Ulverston, Lancashire. This factory has now been in production for five years and it is still being enlarged, the latest development being the construction of a new manufacturing block. Fermentation, extraction and finishing operations are described in the following article.

THE Ulverston factory stands on a triangular, 140-acre site upon which, until 1938, an ironworks had stood. Glaxo Laboratories Ltd. selected the site because it had direct access to the sea and possessed ample railway, gas, water and electricity facilities. In addition, the local labour situation favoured the setting up of a new industry. A further advantage was that Ulverston is comparatively near Glaxo's other antibiotics plant at Barnard Castle, County Durham.

The necessary building licences were obtained towards the end of 1946 and by the following January work had begun. It was destined to be one of the fastest building operations in the history of the company. The work commenced at a time when the whole country was in the grip of an arctic winter and when fuel shortages were acute, but despite the many difficulties the project went ahead very fast. Only sixteen months later, on April 14, 1948, the first fermenter was seeded and a few days later the first batch of penicillin had been produced.

The plant has been built in fairly open country a few miles from the town and is a prominent landmark. The 350-ft. long multi-storey production and laboratories block, with its clean lines and distinctive centre tower, is of typically modern design. Attached to this main block are two wings which house the fermentation units.

When work began at the Ulverston site one of the chief pre-occupations was the demolition of a part of the blast furnaces which threatened to impede building operations. To save time the laying of the 5 ft. thick cellular reinforced concrete foundations and the demolition and clearance of the old installations went on side by side.

The fermenter halls

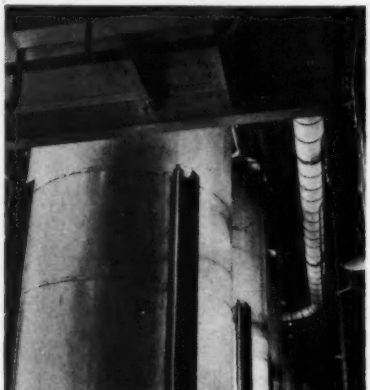
In less than 12 months the first fermenter hall was complete and the foundations had been laid and steel work was in position on the second. The fermenters were installed at the rate of one every two weeks and initially were devoted to penicillin manufacture. At the same time the second fermenter hall was rapidly nearing completion and by November, 1948, half of the fermentation plant was installed and working. In 1949 the second fermentation hall was completed and turned over to large-scale manufacture of streptomycin. Today one hall is devoted to penicillin manufacture and the other mainly to streptomycin.

Much depends on continuous provision of power supplies and in the event of a grid failure diesel driven high-speed alternators are on stand-by to take over part of the electrical load. The fermenter halls, which are steel framed and clad with corrugated asbestos and asbestos roofing, are ventilated by large mechanically-driven extraction fans.

Production control and extraction processes

Most of the multi-storey main building is devoted, in broad terms, to penicillin and streptomycin extraction processes and to various departments ancillary to the fermentation operations.

On the ground floor of the central part of this main block are the loading bays,



A battery of large fermenters used in the production of streptomycin, showing a few of the pipes carrying services to these vessels.

despatch section, plant-rooms and offices. The first floor is devoted to the storing of raw materials and to the batching areas. Inoculum production (for the seeding process), and the chemical control and biological control laboratories are sited conveniently near operating levels on the operating floor. During each fermentation run four-hourly tests are carried out in these control laboratories to check sterility, *p*H, etc. Liquid raw materials (acids, corn steep liquor, etc.) are stored on the third floor.

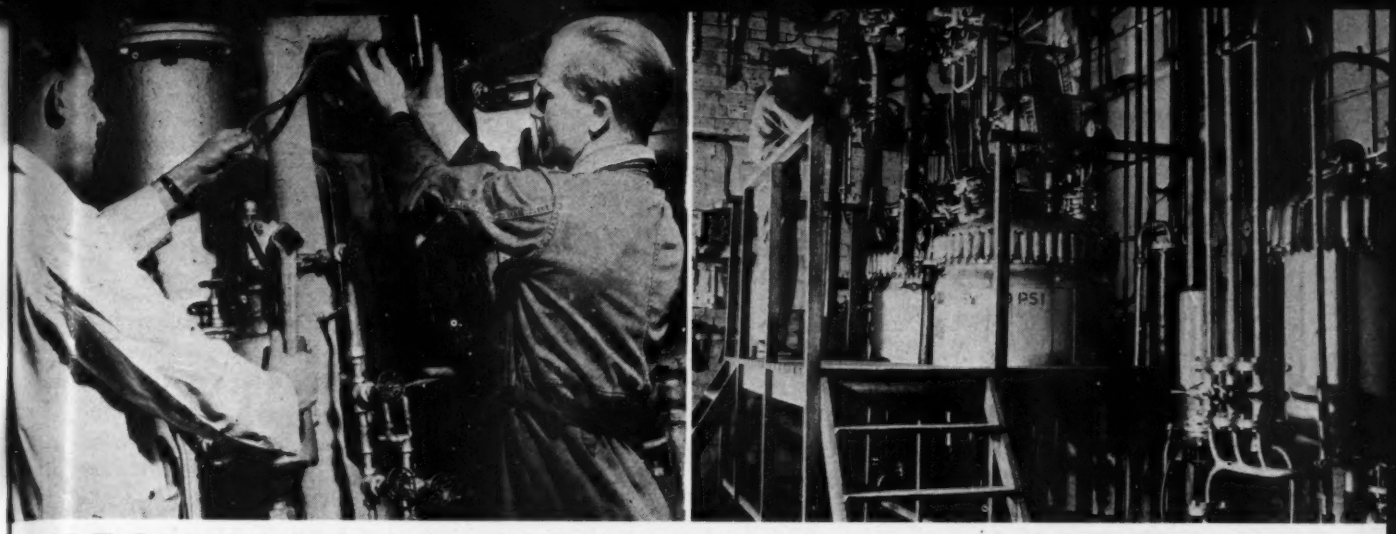
Elsewhere in the main block are sections carrying out extraction processes on both penicillin and streptomycin. The similarity between the production of penicillin and streptomycin ends at the fermentation stage. In penicillin manufacture, batteries of centrifuges are used in the solvent extraction and purification of the crude drug from the broth, followed by its precipitation as a crude salt. The crude penicillin is converted to crude sodium or potassium penicillin which, as solutions, are passed through Seitz filters into stainless steel crystallisers where every precaution is taken to ensure sterility of both plant and product. To these crystallisers, appropriate additions of solvent or procaine hydrochloride are made, under sterile conditions, according to whether the product required is crystalline sodium, potassium or procaine penicillin.

In streptomycin manufacture the drug is separated from the mould by vacuum filtration, adsorbed by means of an ion-exchange process and subsequently eluted with acid. The solution is converted to a crude but crystalline salt, calcium chloride complex. This complex can, in turn, be converted to streptomycin sulphate by precipitating the calcium present, as insoluble sulphate, and precipitating the streptomycin sulphate from methanol. By means of catalytic hydrogenation, and similar removal of the calcium, calcium chloride complex can also be converted to dihydrostreptomycin. Solutions of streptomycin, either the complex or sulphate or of dihydrostreptomycin in water, are subjected to Seitz filtration and freeze drying operations before the drug emerges in its finished state as either sterile streptomycin, or dihydrostreptomycin.

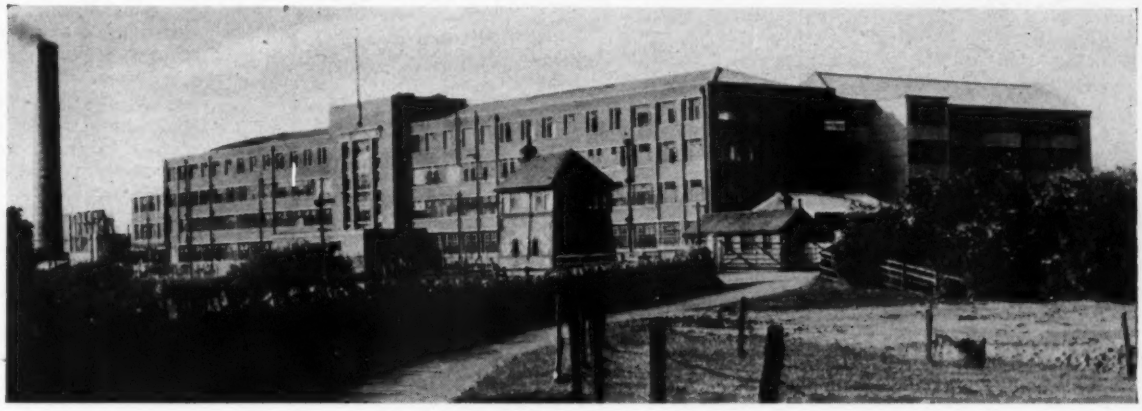
Finishing operations unit

A new unit has been erected on the north side of the main installation to deal primarily with finishing operations on penicillin and streptomycin. This is a three-storey building 160 ft. by 60 ft., of brick exterior, commenced in 1949, and now in full commission. Sterile recrystallisation processes on penicillin, finishing processes on streptomycin and dihydrostreptomycin and streptomycin freeze-drying are some of the operations conducted in this block. Final tests on the finished products are carried out in extensive modern laboratories in the same unit.

The ground floor of the unit is devoted to sterile crystallisation of penicillin. It comprises a crystalliser room, with a battery of stainless steel crystallisers and accompanying Seitz filters ; a sterile off-



Left: **The first stage in the deep-fermentation method of producing streptomycin. A seed tank of several hundred gallons' capacity is being inoculated with the laboratory culture.** *Right:* **Conversion of streptomycin to dihydrostreptomycin. Hydrogen is being passed into streptomycin solution in the presence of a catalyst.**



General view of the Ulverston factory.

loading section, where the containers from the crystalliser section are transferred to trays ; a drier room where solvent is removed from the penicillin by drying under a vacuum in electrically heated driers ; a sterilising section and a sieving room, where, under sterile conditions, the crystalline penicillin is reduced to a uniform smooth flowing powder.

The streptomycin finishing and freeze-drying sections are on the first floor. After the drug has undergone final purification tests in the finishing room, it passes to the freeze-drying unit, where a battery of glistening drying units, lofty ceilings, excellent natural and artificial lighting, tiled walls and gowned operatives make an impressive picture. Also in this sterile area is a cold room, milling room, and wash-up and sterilisation room, and, under the control of the Analytical Department, a sampling department. Distilled and demineralised water is supplied by this section to the plant.

Laboratories

Two departments, Analytical and Process Investigation, are housed in the top storey, the former carrying out the analytical requirements on all finished products and certain raw materials and the latter charged with the investigation of process problems.

The Analytical Department includes two chemistry laboratories, a biological assay laboratory, media preparation and sterility testing sections, balance room and a control laboratory. One of the features of the biological assay laboratory is a plate reading projection section where projectors can handle large assay plates involving 200 samples per day. The laboratory is equipped with several incubators in which automatic temperature recorders give continuous day and night readings.

The refrigerator unit is an interesting installation. Adapted to the company's own specification, the refrigerators are low built and give bench space along their whole length.

In the air-conditioned sterility testing room samples from every batch of penicillin and streptomycin are examined for freedom from contaminating moulds and bacteria. The two chemistry laboratories separately handle penicillin and streptomycin. Distilled water on tap is a special feature of these laboratories.

The function of the Process Investigation Dept. is to suggest improvements in the production processes and to investigate process problems. It comprises four laboratories, Biochemistry and Biological ; Physical Chemistry ; Organic and Analytical ; and Experimental. The section includes a darkroom with polarimeters for penicillin assay and a statistical section.

Power units

In a well-equipped power house are steam turbine and electrically driven air compressors supplying filtered air to the fermentation units ; diesel driven reserve compressors ; electrical switchgear and distribution equipment for supply of current and diesel alternators for load shedding and for use in the event of power failure. During the winter months these diesel alternators supply part of the factory's daytime requirements.

An efficient boiler house installation includes Lancashire oil-fired boilers, supplied with water taken from a neighbouring canal. Adjoining the boiler house is a reservoir of 1.25 million gal. capacity, used as a spray cooling pond.

(*Concluded on page* 328)

How Industry Wastes FUEL and How it Can be Saved

Britain wastes 80% of its hard-won coal; industry alone could easily save 10 million tons a year of steam-raising fuel. These two statements are typical of the many vigorous criticisms of Britain's lethargic approach to the vital, fundamental problem of fuel saving which are expressed in plain, blunt terms in a new British Productivity Report, 'Fuel Conservation,' issued last month.* Since its compilation the decision has been taken to set up in the U.K. a Fuel Efficiency Organisation, for the initiation of which the British Productivity Council has accepted responsibility. The report presents the findings of 12 fuel utilisation specialists drawn from the engineering, heating and ventilating, brewing, chemical, textile and paper industries, who last year made a specific study of power installations and manufacturing and process plants in the United States to ascertain how fuel-saving methods used in that country could be applied profitably to industry in Great Britain. The members of the team, who made the tour under the auspices of the Anglo-American Council on Productivity and the Mutual Security Agency (now Foreign Operations Administration), represented both management and engineers, and their combined opinions stress the urgent need for the better utilisation of all types of fuel, but principally of coal, which 'is the basis of industrial life in Britain and for all practical purposes is the country's only indigenous source of energy.' Below we present a summary of the report.

The magnitude of fuel wastage

THE indictment of waste in Britain is drawn in sweeping terms:

'It is a sad commentary upon our national intelligence that from all the hard-won coal we consume some 80% of the heat is lost, a great deal of it because of ineffective utilisation.'

'It has been estimated that the fuel consumption of manufacturing industry in the U.K. might well be reduced by something of the order of 30% . . .' The team quotes figures showing that about 10 tons of excess air pass through many inefficiently operated Lancashire boilers *every hour*. . . .' All this heat, which is uselessly discharged up the stack, represents an unforgivable waste of fuel on a grand scale. . . . There are 120,000 Lancashire boilers in the U.K. Its repression . . . might reduce the consumption of industrial steam-raising fuel by as much as 10 *million tons of coal per annum*.'

'At least 25% of the heat escapes through the roof and ceiling construction of an uninsulated house'; simple insulation could reduce this loss by 70%.

'The production of (electrical) energy in a condensing cycle . . . involves on the average the wastage of over 70% of the heat available in the fuel.'

In brewing 'too often the firing of boilers is left in the hands of unskilled men who may easily waste 500 tons of coal a year on a relatively small plant—more than the annual production of a miner.'

'. . . if the average mangling performance throughout the British cotton finishing industry were improved to the extent of a general reduction of 5% in the weight of water retained, a saving of coal of the order of 10,000 tons a year would be achieved.'

The paper-making process requires such large quantities of warm water that a good use can always be found for any waste heat it is possible to recover, and 'in the U.K. the paper industry is not taking advantage of the opportunities offered.'

'In Great Britain (railway) locomotives alone consume about 13.5 million tons of high-volatile, large-sized coal per annum . . . at an average efficiency probably not greater than 6%.'

'It is estimated that in Great Britain the entire output of 10,000 miners is wasted every year in the form of unnecessary smoke . . . the Smoke Abatement Society of Great Britain estimates that the nation pays at least £100 million a year on account of smoke.'

Coal a wasting asset

The national position is all the more critical because 'coal is a diminishing asset.' Therefore it is immensely important that we use it to much better purposes than hitherto. . . . Growing industrial productivity will demand the provision of vast additional quantities of energy, both as heat and as power. This energy can come only from coal, and it is a matter of grave doubt whether we can produce sufficient of it to meet these future needs, provide for the extension of other essential services and at the same time increase coal exports unless we improve radically our methods of fuel utilisation. . . . We cannot afford to wait for natural influences to work their effect in the fullness of time. The process of economy must be expedited, and to this end bold measures are necessary throughout industry, not excluding the nationalised undertakings concerned with fuel and power; in fact, the spearhead of a national campaign of fuel economy should be the effective co-ordination of the fuel and power industries.'

Alternatives to coal

In comparing sources of energy other than coal in Britain and America, the team emphasises that the alternatives in Britain are very limited, and summarises the situation as follows:

Natural gas. 'It is only of recent years that the full potentialities of natural gas in the U.S. have been realised and exploited, but the industry is now expanding at an extremely rapid rate. . . . To all intents and purposes no natural gas is available in the U.K.'

Water power. 'Of the total resources of water-power in the U.S. only about one-fourth has so far been harnessed. Nevertheless, this represents about 30% of the total amount of electrical energy produced in the country. In the U.K. the greater part of the natural water-power resources which could be economically harnessed has already been exploited or is planned for development. . . . The possibilities which lie in tidal power are as yet not fully determined.'

Other sources of energy. 'In both the U.S. and the U.K., experiments are at present being conducted on the underground gasification of coal as a means of recovering a proportion of the heat energy available in coal seams which cannot be mined economically. The successful development of the system could liberate the energy contained in many million tons of coal which would otherwise be left in the ground, but although experiments are proceeding the indications are that the method will not make any appreciable contribution to the energy resources of the U.K. in the immediate future. . . . The British Electricity Authority is now carrying out experiments with a view to deter-

* By the British Productivity Council, 21 Tothill Street, London, S.W.1 (5s., post free, excluding air mail).

mining the extent to which the power of natural wind forces can be adapted for the generation of electrical energy. . . . A study is proceeding of the economics of methane gas recovery from underground coalmine workings. . . . In spite of the progress which has been made in the field of nuclear fission, it seems probable that it will be many years before its application to power generation can be regarded as an economic possibility. From what has been said, however, regarding the relative energy resources in the U.S. and the U.K., it must be obvious that for us the development of atomic energy on a commercial scale is a matter of pressing necessity in replacement of our rapidly diminishing reserves of coal.'

What fuel conservation can offer

'It is within our capacity as a nation to save, on the present level of industrial activity, no less than 30 million tons of coal p.a. without impairing any services.' This figure is a conservative one and it is felt that savings considerably in excess of this amount would be possible if capital could be made available to replace all obsolete fuel-using equipment. This forecast is based on the results which emerge from the work of the second Fuel Efficiency Committee set up by the British Government in 1941.

'We in Britain can claim to have the great advantage of long industrial experience and a great store of "know-how." We can claim, too, that our best plants are as efficient as any in the world. It would be unnecessary, therefore, to make any comparisons with our American contemporaries on fuel conservation if we could bring practice in the rank and file of British industry up to standard. It is, however, this very rank and file that consumes in the aggregate the bulk of our coal, and it is here that primitive and wasteful utilisation takes place.'

'In the production or application of heat and power American industrial practices are parallel with those of Britain, but the outstanding difference is that American industry is quicker to adopt new methods and follows a bolder course in the scrapping of inefficient plant.'

Two significant lines of attack

The team emphatically commends to the attention of British industry at large two significant lines of attack adopted in the American drive for fuel economy. The starting point of one was consideration of the relative costs of mechanical power and man-power: 'The American industrialist takes full advantage of mechanised power and is prepared to give his workers the maximum use of it because he realises that it is infinitely cheaper than human effort. He has accepted and put into practice the principle that it is much more important to keep the machine, not the man, working hard. This is claimed to account largely for the high rate of productivity in American industry.' The other was the inception of the dual-purpose generating station: 'One possible method of improving efficiency in the public generation of electricity is by the adoption of dual-purpose stations, producing and selling both heat and power. Such stations would be equipped with back-pressure or pass-out turbo-generators supplying exhaust or bled steam to nearby industrial, commercial or domestic premises.' Word pictures of what has been done at the trading estate at Slough, and could be done in other U.K. districts, notably Warrington and Kidderminster, are given on pages 34-38 of the report.

The meaning of fuel efficiency

'Efficiency in the use of fuel should not be regarded as meaning only thermal efficiency. It comprises the overall effect of methods of fuel utilisation upon the process as a whole, including labour costs, quality of product, rate of production and so forth. Within this broad definition there is wide scope for economy through the adoption of good practice. It governs productivity.

'By and large, British industry has not replaced or materially modified its fuel and power equipment since the first world war; it is old and inefficient. But machinery that was perhaps good enough when coal was in abundant supply and cost as little as 10s./ton at the pithead is not good enough today and remains an obstinate barrier to the achievement of real fuel economy.

The heart of the problem

'Somehow this barrier must be removed; an incentive must be provided to break the deadlock. This is the heart of the problem and it turns on the financial predicament of industry at large. It is unlikely that industry will maintain and improve its standard of fuel utilisation unless it is actively assisted, persuaded, or even coerced to do so by legislative means. Given inducement, the many plans and projects that have been developed but perforce postponed will be brought out of their pigeon-holes.'

A State responsibility

'By taking control of the production of coal, gas and electricity the State has accepted responsibility for the fuel services. It cannot therefore stand aside and permit waste or improper use of these fuels to continue . . . the fuel technologist has always felt nationalisation of the basic fuel industries to present great possibilities of substantial benefit, *provided real co-ordination could be achieved between them.* In the long term, concern would be with such matters as:

- 'Integration of gas and electricity production on the same site.
- 'Generation of power from gas works waste heat and/or from an orthodox power plant using coke breeze, both supplying power to the grid.
- 'Supply of pass-out steam and power from a generating station to a gas works.

'In the short term, many vexed questions await solution, among them:

- 'Is it in the national interest that electricity, a costly and refined product, should be used for space heating, except where gas is not available?
- 'Is it not essential, in view of industry's future needs for power, that the functions of electricity be confined to the provision of power, light and certain specialised heat processes?
- 'Is not gas the right fuel to retain on tap for space-heating purposes (occasional heating)?
- 'Seeing that the base load of space heating can only be carried by solid fuel, is it not in the country's best interests that smokeless fuels be used, particularly in the domestic sphere?
- 'Can we produce more smokeless fuels, improve their distribution and reduce their cost?
- 'Where electricity is available, should gas lighting be used for public services?'

No evidence can be found, says the team, of any attempt made to co-ordinate on either the long- or the short-term policies indicated. On the contrary, it states: 'We see each industry—coal, gas and electricity—consolidating its own policy and pursuing its own line of action, presumably because the wider national interest is none of its responsibility.'

'With the country looking for an authoritative line of action, we suggest one bold stroke to set us on the right road: enact legislation to create a permanent and non-political Fuel and Power Board. Let that board formulate whatever policy is necessary, but above all let it get on *first* with co-ordination.'

Wasteful use of steam

'Steam is perhaps the commodity most universally consumed in British industry and perhaps the worst used, primarily because our traditional practice has been to divorce processing departments from engineering departments. . . . Too often the works engineer who knows, or ought to know, the cost of these services has no jurisdiction whatever in the department or processes in which steam is consumed. His protests at its wasteful usage seldom fall on sympathetic ears, notwithstanding that for every 1% that might be saved in its production 3% or more might be saved in its utilisation. It is this kind of traditional practice in industry which it is necessary to change, and change can come only from a better appreciation of the problem by executives.'

Measures that can be taken to avoid the very heavy waste of steam in industry are well established and certain of them are dealt with in a chapter called 'Wastage of Energy in Factories,' which we shall publish in our next issue.

Water Pollution Research

'WATER POLLUTION RESEARCH, 1952,' recently published,* includes the reports of the Water Pollution Research Board and of the Director of Research, which describes the work of the Water Pollution Research Laboratory during the year.

Disinfection of water

Work has been continued on the effect of various substances on the disinfecting action of chlorine on bacteria in water. One interesting observation is that the very small bactericidal action of chlorine in water containing peptone is greatly increased if ammonia also is present. Improvements have been made in methods of enumerating *Streptococcus faecalis*, a bacterium which, like *Bacterium coli*, is an indicator of faecal pollution. Another section of the work on water deals with the removal, by processes commonly used at water works, of radio-iodine which is used in medicine, and may be discharged in small amounts to streams as a constituent of sewage effluents.

Sewage treatment

Work at Birmingham during the year has confirmed that the four large percolating filters there, when treating sewage by alternating double filtration, operate more efficiently when each distributor revolves once in 30 min. than when it revolves in 1 to 5 min. Not only has the biochemical oxygen demand of the effluent from the filters with the slower rate of rotation been lower, but the degree of nitrification has been considerably higher than in effluent from the filters with rapidly revolving distributors. One of the main objects of the work at Birmingham now is to try to explain these differences.

Results are given of the operation, for 13 months, of five small sewage-treatment plants, each comprising a septic tank and filter, and treating sewage from some 10 to 20 persons. The septic tanks tested included single rectangular, two-storied, and double types. All of these gave substantially similar results, as did also the percolating filters, except for one fitted with a revolving distributor which required frequent attention. With a volume of filtering medium of 10 cu. yd. for each 10 to 20 persons, effluents of very good quality were obtained.

Experiments made at Stivichall in conjunction with the Gas Research Board have now shown that spent liquor from the gas works at Hinckley can be treated in a percolating filter in admixture with sewage, in a concentration up to 3% by volume, without causing much deterioration in the quality of the effluent. This proportion is, of course, very much higher than is possible with gas liquor of the ordinary type. At Hinckley the hot gas is treated by electrostatic precipitation with the object of reducing the concentration of higher tar acids in the liquor. At the Hinckley works, also, retort-house liquor is disposed of separately and it is now proposed to begin experiments at Stivichall in which the liquor from Hinckley, with an appropriate amount of retort-house liquor, is treated in admixture with sewage.

Industrial waste waters

Some work has been done on the treatment of the black liquor resulting from the kiering of cotton. After some difficulty an active sludge was developed which, when mixed with the neutralised liquor, caused rapid anærobic fermentation with evolution of a gas containing about 80% methane.

Experiments have been made on the effects of treating simple and complex metallic cyanides in admixture with sewage. The aim of this work was to determine the maximum concentration of cyanides (which are often constituents of waste waters from electroplating) which could be treated in admixture with sewage by biological filtration without causing deterioration in the quality of the effluent. At first the permissible quantities were small, but as the experiments continued the tolerance of the filters increased very markedly. For example, effluents from the treatment of sewage containing potassium, zinc and cadmium cyanides in concentrations equivalent to 100 p.p.m. HCN, contained on the average less than 0.2 p.p.m. cyanide. Moreover, the biochemical oxygen demand of the effluents was not greatly different from that of effluents from control filters. Experiments have now been put in hand to ascertain whether waste waters containing cyanide could be treated, without admixture of sewage, by biological methods.

Toxic waste waters

It has been shown that the toxicity of potassium cyanide in small concentrations increases markedly as the concentration of oxygen in solution is reduced; even near the saturation value a small reduction has a considerable effect. This is of considerable importance both in the design of tests for toxicity and in the effect on fish of toxic substances in rivers.

Survey of Thames Estuary

The largest section of the report deals with work on the Thames Estuary. The subjects studied include the distribution of salt water and fresh water, the effect of rough weather in raising the level of dissolved oxygen in the water, the relative importance in polluting effect of discharges of organic matter contained in fresh-water streams, sewage effluents and industrial wastes, the particle size of deposits in different parts of the estuary, the important part played by suspended solids in contributing to the biochemical oxygen demand of estuary water, the effect of oxygen in inhibiting the reduction of sulphate to sulphide by bacterial action and the catalytic effect of mud in promoting the oxidation of sulphide by oxygen in solution.

* By H.M. Stationery Office, London, 2s. 6d. net.

Foaming rivers

The report refers to the increased production of foam in sewage works and in rivers to which sewage effluents are discharged. The presence of large quantities of foam in rivers has been reported from many places during the year and it is generally believed that the foam is due to the increase in the use of synthetic detergents of different types. The board points out that, though the problem is one to which serious attention will eventually have to be given, the laboratory has been unable to begin work on the problem because of its heavy existing commitments.

Pollution of beaches by oil

The Ministry of Transport has set up a committee to study the problem of the pollution of beaches by oil. The Director of Water Pollution Research is a member of the committee, which includes representatives of oil companies, ship owners and other interests concerned. Work on possible ways of preventing the pollution is being carried on at various laboratories and the oil companies have carried out large-scale trials at sea at which members of the staff of the laboratory have been present.

PENICILLIN AND STREPTOMYCIN

(*Concluded from page* 325)

Engineering workshops

During the first five years of the factory's history, the Engineering Department was housed in old buildings, hardly suitable for efficient operating. In 1952 a new building was completed which houses the central engineering workshops, engineering stores and engineering department offices. The buying and stores departments and a conference room are located in the same building.

Improvements and extensions

Since the company took over the site in 1948 a number of exterior improvements have been carried out. Cultivation of a slag heap, estimated to hold over 6 million tons of slag, and a legacy of the old ironworks days, has started. Several hundred sycamores, elders and limes have been planted and are beginning to stimulate vegetation.

The latest development at Ulverston is a new multi-storey production block now in an advanced stage of construction.

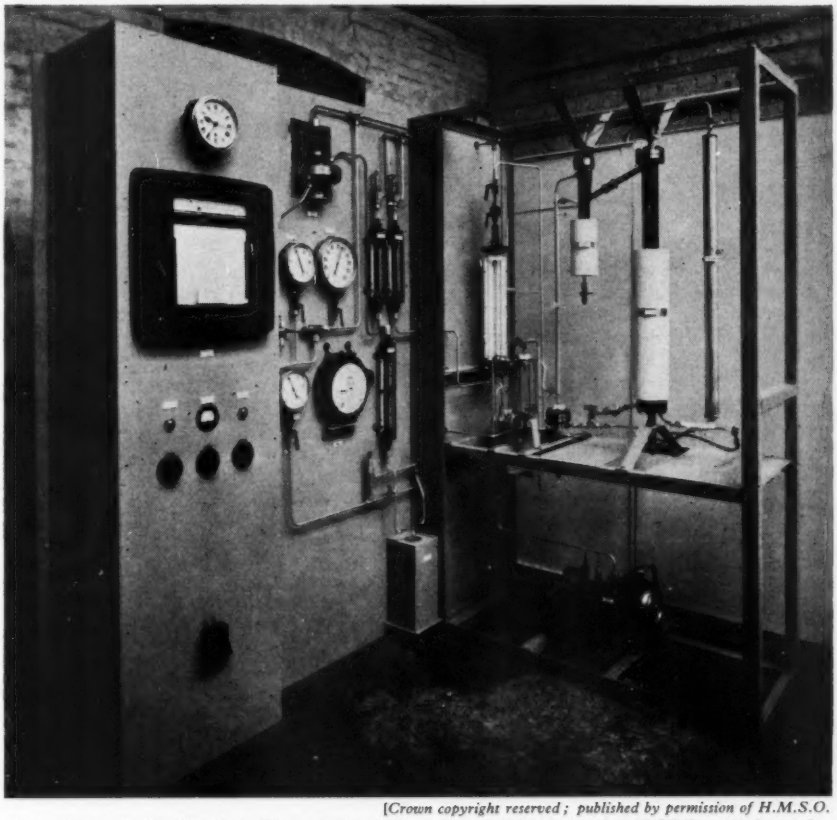
A Progress Report on
THE FISCHER-TROPSCH PROCESS

Although there are no commercial Fischer-Tropsch plants in Britain, considerable research and development of this process for producing oil and chemicals from coal has been carried out by the Fuel Research Station, Greenwich, since 1935. As a result of this work, and of its contact with research workers abroad, the Station has amassed much valuable information on the process and its application in the chemical industry. This information is freely available from the Station. The following notes summarise Fischer-Tropsch developments since the process was first discovered in Germany in 1925. Especially interesting is the possibility of using the process for the production of chemicals and waxes in conjunction with the manufacture of liquid fuel. Such projects would offer new opportunities for British plant manufacturers and chemical engineers.

IN 1925, two German chemists, Franz Fischer and Hans Tropsch, discovered that carbon monoxide and hydrogen, the main constituents of water-gas derived from coke or coal, would react in the presence of nickel, cobalt or iron catalysts at atmospheric pressure and a temperature of about 200°C. to form a mixture of hydrocarbons approximately equivalent to a crude petroleum oil. This reaction is the basis of what is known as the Fischer-Tropsch synthesis which provides a means of producing petrol, diesel and jet fuels, waxes and a wide range of chemical products from coal.

In its original form, the process was used in nine German plants during the period 1939-45 and produced annually about 500,000 tons of liquefied gas, petrol, high-grade diesel oil and other products.

Interest in this process is world-wide and is not confined to countries without indigenous petroleum. In the U.S., for example, both Government and industry have spent large sums on research and development work on the process, culminating in the construction by industry of a commercial plant at Brownsville, Texas, to produce 300,000 tons p.a. of high-grade petrol from natural gas and the erection by the U.S. Bureau of Mines of a 300-tons/year 'demonstration' plant at Louisiana, Missouri, based on coal as raw material.



[Crown copyright reserved; published by permission of H.M.S.O.

Experimental liquid-phase Fischer-Tropsch unit, exhibited on the D.S.I.R. stand at the Engineering, Marine and Welding Exhibition in London last month.

Economics

The major cost in the operation of the Fischer-Tropsch process is that of making the synthesis gas, the required mixture of carbon monoxide and hydrogen which, in turn, is largely dependent on the cost of coal or other basic raw material. At the present price of coal relative to petroleum oil, the operation of the Fischer-Tropsch process to produce liquid fuels as main products is not commercially economic in this country or in the U.S. The work of the Bureau of Mines in America and of the Fuel Research Station in the U.K. is to a large extent, therefore, concerned with the possibility of future shortages of natural petroleum oil, either local or world-wide. No commercial Fischer-Tropsch plant has ever been erected in Britain and, so far as is known, no plans exist for building one.

Where very cheap coal is available, production of synthetic oil can compete with imported petroleum oil and at the present time a Fischer-Tropsch plant to produce about 200,000 tons p.a. of petrol, diesel oil and waxes from low-grade coal is in course of construction at Coalbrook, Orange Free State, in the Union of South Africa. Serious consideration has been given to the erection of a similar plant in Southern Rhodesia where similar conditions prevail.

Since the process was first industrialised in Germany in 1936, it has undergone many improvements and modifications. Active and durable iron catalysts have been developed which are cheaper than the cobalt catalyst used in the original German plants and confer greater flexibility on the process both with respect to the nature of the gaseous raw material and process conditions which can be employed and to the nature of the products which can be obtained. The ratio of carbon monoxide to hydrogen in the gas mixture can be varied over a wide range and even a mixture of carbon monoxide and steam can be used as feed material. Temperatures within the range 200 to 350°C. and pressures from atmosphere to 50 atm. can

be employed. The reaction products can consist almost entirely of gaseous and low-boiling olefins which makes possible the production of 80-octane motor fuel as the main product, or to the extent of 60% or so of solid waxes. The products can consist almost entirely of hydrocarbons or predominantly of alcohols and other oxygen-containing compounds. The primary products are suitable for conversion into lubricating oils, synthetic fatty acids and detergents by further chemical processing.

Chemical engineering progress

Considerable advances have been made on the chemical engineering side of the process. The synthesis reaction is strongly exothermic (over 7,000 B.Th.U. released per lb. of product made) and the production of the required products is highly dependent on efficient control of catalyst temperature by removal of the heat of reaction. In the original German plants this was achieved by using a fixed bed of catalyst granules packed into water-cooled tubes or into a vessel equipped with finned tubes carrying cooling water. In either case the catalyst temperature was controlled by regulating the steam pressure in the cooling system. The low rate of heat transfer obtained in such a system severely limited the permissible throughput of the reactors and the degree of conversion per pass.

The fixed-bed system has been improved since the war by the Ruhrchemie A.G. (the licensors of the original process) and the space-time yield increased to about five times that achieved in the original reactors. The first stage of the South African plant is to be equipped with reactors of this improved fixed-bed type.

By utilising the 'fluidised-solids' technique for the synthesis very much higher rates of heat transfer from the powdered catalyst to the cooling water can be obtained. In pilot-plant operations with this technique, space-time yields 20 times greater than those obtained in the original fixed-bed plants have been achieved. The fluidised-catalyst system suffers from the disadvantage of requiring a rather narrow range of conditions for successful operation and is, in any case, restricted to the production of gaseous and low-boiling hydrocarbons (petrol) and low-molecular weight oxygenated compounds. The second stage of the South African plant will employ a special type of fluidised-catalyst system devised by the M. W. Kellogg Co.

Liquid-phase systems

Various liquid-phase systems have been tried out in the Fischer-Tropsch process. In these, the catalyst is in direct contact with a non-volatile liquid cooling medium and, although the presence of this medium retards the rate of the synthesis reaction, very efficient cooling of individual catalyst particles is obtained and the production of undesired products such as methane is minimised. In the Fuel Research Station's view, the most promising of these techniques is the "slurry" process, in which finely-powdered catalyst is suspended in molten wax and the synthesis gas is passed up through the suspension. Volatile reaction products pass out of the reactor with the effluent gas stream; non-volatile waxes and heavy oil remain in the slurry, whence they are removed through a filter to maintain a constant level of liquid in the reactor.

Both the liquid-phase slurry and the fluidised-catalyst systems possess the advantage of permitting continuous replacement of catalyst in order to maintain a constant level of catalyst activity and hence product quality. In the fixed-bed process the reaction temperature is normally increased with time to maintain the desired level of conversion until a certain stage of catalyst deterioration has been reached, when the contents of the reactor must be discharged and replaced by fresh catalyst.

Research at the F.R.S.

At the Fuel Research Station of the D.S.I.R. a programme of research and development work on the Fischer-Tropsch process has been continuously pursued since 1935. At the present time the equipment available for this work includes a number of laboratory-scale units for catalyst development and testing and for studying the effect of process conditions on catalyst performance and product quality. For the study and development of process techniques two fluidised-catalyst units and four liquid-phase units are available. To obtain more reliable chemical engineering data for various reaction systems and to facilitate the design of a suitable reactor for commercial-scale operation a pilot plant to give 50 to 60 gal./day of products has been built. This plant has been equipped with two reaction vessels, one designed for fluidised catalyst and the other for the slurry process.

In addition to this catalyst and process development work, the more fundamental aspects of catalyst action and reaction mechanisms have been continuously under investigation since the inception of the programme, and valuable contributions have been made to our knowledge. In current work on these aspects, radioactive carbon is being used as a tracer.

At the end of the war in 1945 the Director and members of the staff of the Fuel Research Station played a leading part in collecting and collating the vast amount of information available in Germany on the Fischer-Tropsch process and the fact that the information thus made available to Allied readers is so complete and accurate is in no small measure due to the previous knowledge of the process which the investigators possessed. Since the war close personal contact has been maintained between working on the process at Greenwich and those working in the field in the U.S. and Germany.

Opportunities for British plant manufacturers

Although, as stated earlier, the production of liquid fuel as the main or sole product is not a commercial proposition in the U.K., the possibilities of combining oil synthesis with other processes such as town's gas manufacture, electricity generation, pig-iron production or calcium carbide manufacture merit examination, and the production of high-melting-point waxes or oxygenated products by the Fischer-Tropsch process might well prove to be economic. The possibility of large synthetic oil plants being built in areas where cheap coal exists and imported oil is costly could provide opportunities for British plant constructors and engineering constructors.

Pyridines from petroleum

Chemists and petroleum engineers at Phillips Chemical Co., Port Adams, Texas, have developed a commercially practical method for producing methyl vinyl pyridine (MVP) and other valuable pyridines synthetically from petroleum raw materials. A special plant is now under construction.

As a preliminary step, acetaldehyde is converted into paraldehyde. The latter is prepared by the trimerisation of 3 moles of acetaldehyde to 1 mole of paraldehyde in the presence of a small amount of sulphuric acid catalyst. The combined acetaldehyde and sulphuric acid are fed continuously into the polymerisation reactor, the exothermic heat of reaction being removed by cooling water in an external heat exchanger. The acid catalyst is neutralised and the paraldehyde is purified by fractionation.

The next step is the synthesis of methyl ethyl pyridine (MEP). It consists of a liquid-phase reaction of paraldehyde with ammonia. In addition to the main product, a certain amount of 2-picoline, 4-picoline and heavy pyridine by-products are formed. The reaction effluent goes to separation equipment and excess ammonia is recycled to synthesis. In the separation equipment, various by-product pyridines, including MEP, are recovered. The MEP is sent to surge storage until used as feed in the MVP section of the plant.

The main dehydrogenation reaction produces 2-methyl 5-vinyl-pyridine; and also a certain amount of pyridine, as such, 2-picoline, 3-picoline, 3-ethyl-pyridine, lutidine (2.5-dimethyl-pyridine), and 3-vinylpyridine by-products. MVP is recovered as a final product.

Solid-drawn copper and copper alloy tubes. The British Standards Institution has just published a revised edition of B.S. 378 which supersedes the 1941 edition. It costs 2s. 6d.

The previous issue covered solid-drawn 70/30 brass and 70/29/1 brass tubes. The present revision includes, in addition to these alloys, tubes in copper, aluminium brass, copper-nickel and aluminium bronze (7% aluminium).

Plant and Equipment

Distillation trays

In certain processes, particularly those in which liquid load is high, as in de-ethanisers, de-propanisers, stabilisers and absorbers, or where column height is limited, a new, vapour-liquid contacting tray is claimed by the makers to have striking advantages over the bubble-cap type. For a similar separation efficiency per foot of column height, *Turbogrid* trays, as they are called, can have up to 100% more capacity than a well-designed bubble-cap tray and as much as 80% less pressure drop per tray.

In construction the tray consists merely of a flat grating extending uniformly over the entire column cross-section. The rectangular struts are of dimensions and number appropriate to the application and so designed that the flow of liquid is turbulent, hence the name, with good vapour-liquid contact. Separation is equivalent to that in a bubble-cap tray, yet the simple shape and greatly reduced flow resistance give the tray much greater capacity and much less pressure drop.

W. J. Fraser & Co. Ltd. design and make the tray in England under licence from Shell, who hold the patents.

Pipe-line filter unit

Some years ago, the Royal Doulton Potteries introduced a small hard-glass filter unit, designed primarily for the laboratory or pilot plant, where it is now used extensively for operations involving the filtration of both corrosive and non-corrosive liquids under negative or positive pressure. Now it is also being used in production processes where, in many instances, several units are employed in parallel to achieve increased capacity. In this unit, known as the F. 87A, a porous ceramic filter candle or element, 8 in. long and approximately 1 in. diameter, is provided with a glass casing whereby it can be fitted into a pipeline.

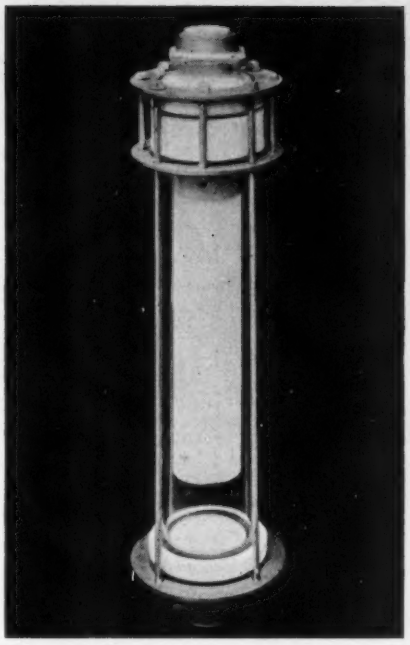
The development section of the company has since been investigating problems pertaining to larger units of similar characteristics, with the result that it is now possible to undertake manufacture in a range of sizes to meet particular problems.

Most important among the characteristics of these new pipeline filter units is the fact that the liquids passing through the unit have no contact with metal or similar materials of low corrosion resistance. Apart from the porous ceramic element, the stoneware end fittings and the hard-glass tube which surrounds the filter, the only other material with which the liquor can have any contact is that which is used for the construction of gaskets.

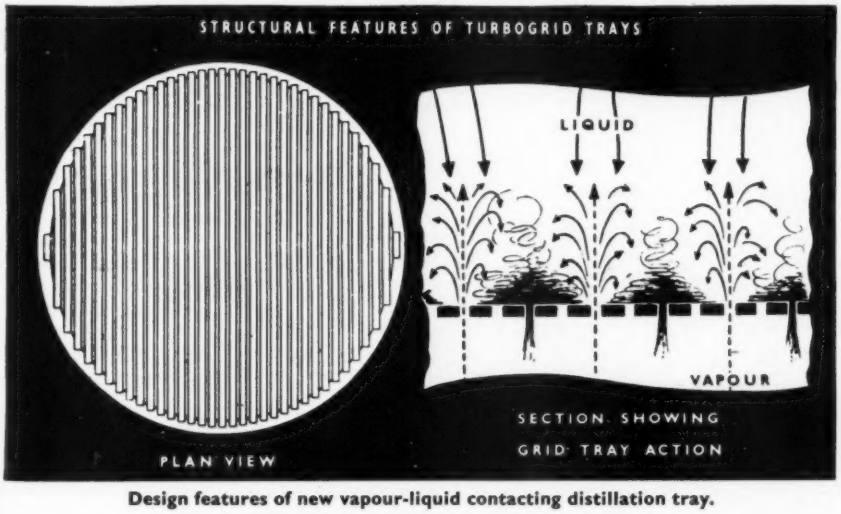
The selection of the most suitable material for gaskets presents a certain problem. One can employ either natural or synthetic rubber, compressed asbestos and certain of the plastics, but all of these have limited resistance to corrosion. Development work now in progress should make possible the use of PTFE, which will go a long way towards solving the problem.

Since the filter element is clamped into position in the outlet fitting independently of the rest of the assembly, the glass casing can be removed for periodic cleaning without disturbing the element and without fear of any unfiltered liquor penetrating into the clean filtrate.

A typical unit takes a filter element 18 in. long and $3\frac{1}{2}$ in. outside diameter, giving an effective surface area of approximately $1\frac{1}{4}$ sq. ft. The element is encased in a glass tube of approximately $4\frac{3}{4}$ in. bore and has at either end chemical stoneware inlet and outlet connections. The unit shown in the photograph has end connections of the type used in chemical stoneware fixed-flanged piping; alternative end connections can be provided when the unit is to be linked up with other types of pipelines.



Filter unit for pipelines consisting of ceramic 'candle' in a glass case.



Design features of new vapour-liquid contacting distillation tray.

Rock crusher's performance

The reduction of materials suitable for making concrete aggregate is a routine job in most parts of the country and presents few difficulties. But in the case of John W. Swindells Ltd., New Mills, near Buxton, Derbyshire, it presented many problems which arose principally from the fact that their aggregate is produced from rock containing an exceptionally high silica content. The actual analysis was: silica 91.08%, titanic oxide .18%, alumina 4.42%, ferric oxide 1%, lime .03%, magnesia .15%, potash 1.89% and soda .50%.

The abrasive action of such material is obvious and the resultant wear and tear on the crusher jaws made it necessary to turn the jaws every two months and renew every six to seven months. Quite apart from the cost of replacement, the expenses arising from idle machine-time, labour and the disruption of production proved very costly.

The problem was solved by the installation of a Pegson 24-in. *Gyrasphere* crusher. During a period a little over 18 months, it has crushed 17,000 tons of aggregate, yet the concave and mantle have only just been replaced. In addition, there has been a reduction in undesirable fines by over 50%.

The crusher is constructed on the principle of an inverted pestle and mortar. There is a large feed opening and the design permits unobstructed and unlimited

feed. This principle enables the maximum number of crushing blows to be made at high speed before discharge and wear and tear on the manganese crushing faces is greatly reduced. The product is of cubical shape and the dust percentage is reduced to negligible proportions. Made by Pegson Ltd., the crusher is also available in 36-in. and 48-in. sizes.

Cam-operated metering pumps

A French company has developed a metering pump claimed to have many advantages over existing pumps in achieving quantity control, owing to its design and particularly to the operation of the piston.

The piston control is embodied in the combined action of a cam and a drawback spring. The cam, operated by the motor of the pump, drives the piston during the delivery stroke, whilst the spring draws the piston back during the suction stroke in accordance with the shape of the cam which governs the displacement throughout. The flow variation, *i.e.* the variation of the piston stroke, is obtained by inserting, in the return stroke of the piston, a movable and adjustable limit stop.

The shape of the cam is calculated to satisfy the two criteria of accurate dosing. It permits the departure of the piston on its suction stroke with a high initial speed and provides for a standstill of adequate duration at the end of the suction stroke; this is achieved independently of the piston stroke adjustment. With a simple turning of a wheel, either during the operation or during the standstill of the pump, the limit stop is moved and the flow regulated at will. The setting can be carried out with great accuracy so that the flow can be accurately re-set for any quantity for which it had been set previously. The makers say that the output can be reduced virtually to single drops.

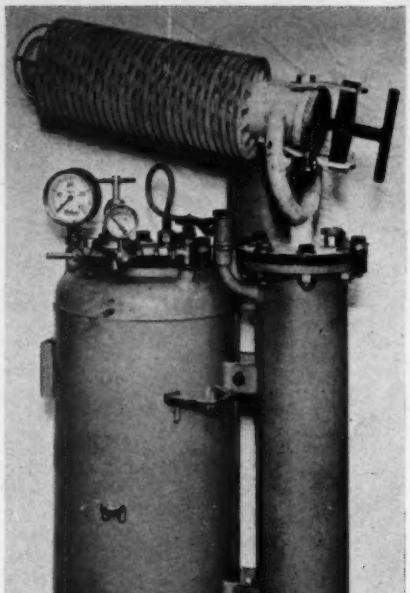
The pump is known as the ' S.E.R.D.I.' and is produced by the Société S.E.M. The maximum flow varies between 250 cc. and 1,200 l./hr. The design permits the combination of any desired number of pumps in a multipump set, operated by a single reduction gear motor. It is therefore possible to provide for interrelated quantity control of one or more important flows of liquids. The delivery pressure may rise to 250 kg./sq.cm.

One application is the control of one or more flows as a function of certain parameters. For instance, the flow might be governed by the flow of a ' pilot liquid,' a temperature, a pressure, a *p*H value or by maintenance of the titration standard of a solution, etc. In this respect, the S.E.R.D.I. pump can serve as an automatic flow regulator, governed by a specific condition.

It is claimed further that, with the aid of such a group of cam-operated dosing pumps worked by a single reduction gear motor, it is possible to solve the problems inherent in the regulation of the flow of several liquids which are to be brought into contact in given (and adjustable) proportions or inherent in the simultaneous feeding of parallel production lines. In this way it is possible to combine up to 20 associated pumps.

The pump consists essentially of two parts: a mechanical part comprising the piston operating and regulating gear, and a hydraulic part comprising the pump body, piston and valves. These two parts are independent of each other so that there is no pollution of the pumped liquids and, on the other hand, no danger of the pumped liquid attacking the motor mechanism. The mechanical parts are standardised and exchangeable; they are operated by a standard reduction gear motor.

The hydraulic part is designed to deal with corrosive liquids, being of stainless steel and plastics construction.



One charge of chemical candles gives 35 cu. ft. of oxygen in 15 min. in this new portable generator.

For further details of plant and equipment please use the coupon on page 338

Portable oxygen generator

A low-cost portable oxygen generator, the *Oxybloc*, is now being marketed by K. W. Chemicals Ltd. Measuring 61 × 21 × 31 in. and weighing 265 lb., it can be transported by a light vehicle.

The machine consists essentially of a tank for oxygen storage and a scrubbing container, the upper parts of which carry a steel retort with cooling ribs, together with the control and regulating devices (valve, pressure gauge, etc.).

Oxygen is produced by burning chemical candles in the retort. The gas goes down a pipe, passes through a purifying solution and is stored under pressure in the tank. A regulator is provided on the outlet pipe to control at will the pressure required for use in the torch. The working procedure is as follows:

Before loading the cylinder, ignition is induced by a special tool which powders a very small quantity of the topmost charging candle, after which a match or a piece of burning wood is held in the powder until a reaction is taking place satisfactorily.

A cylindrical barrel is then loaded with the ignited candle container.

Impure gas is given off at the head of the cylinder and forced through piping to a filter section, which scrubs and purifies before delivering into the storage cylinder 99.5% pure oxygen. The complete action takes about 15 min. and each charge gives 35 cu. ft. of oxygen at a commencing pressure of about 200 p.s.i.

Thus the machine is able to provide ready-to-use oxygen in 15 to 20 min. The makers say that it has already had a great practical success in certain parts of Africa where there is a constant call for an on-the-spot mobile welding repair unit.

The apparatus should be available at an ex-store price of under £200.

Vibration generators for research

Specialised vibration equipment is now being manufactured and marketed by Goodmans Industries Ltd. It comprises a permanent magnet vibration generator and associated electronic amplifiers complete with a R.C. oscillator. Vibration generators are based on the moving-coil principle operating a centrally-moving armature. By this means specific vibratory conditions can be simulated and the effects of sudden acceleration on materials, structures and components can be assessed.

An application in chemical engineering research is that of vibrating a column of liquid for liquid-to-liquid mixing. The weight of the liquid, acting downwards on the vibrator, is suspended by means of a helical compression spring, the stiffness of which is adjustable by three screws placed 120° apart.

The bottom of the glass column is sealed by a strong corrugated diaphragm, the centre of which is attached to the driving rod of the vibration generator.

World News

GREAT BRITAIN

More courses in industrial technology

The Ministry of Education has recently drawn the attention of Local Education Authorities, Regional Advisory Councils for Technical Education and Regional Academic Boards to the urgent need to expand the provision of the advanced short courses in industrial technology.

Last year more than 500 of these courses were provided covering such subjects as Recent Developments in Electronic Techniques, Principles of Mass and Flow Provision for Productive Engineering and Recent Developments in Dyestuffs; but the Ministry thinks that the demand for these courses would increase considerably if their existence were more widely known in industry.

It has therefore asked Local Education Authorities, Regional Advisory Councils for Technical Education and Regional Academic Boards to make a special survey of the need for advanced short courses so that Local Education Authorities and Universities may make additional provision. The Ministry has also arranged to keep a list of all courses and to send particulars of them to the Federation of British Industries and the National Union of Manufacturers, who will inform their constituent bodies.

Employers and individuals are also invited to make suggestions for courses, either to the appropriate Regional Advisory Council or direct to the Ministry.

Fuel efficiency exhibition

The Fuel Efficiency Exhibition to be opened by the Earl of Derby on November 18 in the City Hall, Manchester, will be one of the largest shows of its kind ever presented.

New types of fuel-economy apparatus, for both industrial and domestic use, will be on show for the first time. The exhibition will last from November 18 to 28.

Commercial Solvents appointments

Mr. G. H. Duncan and Mr. E. J. Farrar have been appointed to the Board of Commercial Solvents (Great Britain) Ltd.

Industrial safety appointment

Mr. A. E. Bagg has left Industrial Guarding Equipment Ltd., to take up his appointment as managing director of Press Guards Ltd., Birmingham. Well-known in industrial safety and accident prevention circles, Mr. Bagg will be initiating a vigorous policy of expansion in his new company.

Platinum exhibition

The Duke of Edinburgh is opening the Platinum Metals Exhibition at Grosvenor House, London, on October 19. The exhibition, organised by the Institution of Metallurgists, is being held to mark the triple jubilee of the discovery of palladium by the British scientist W. H. Wollaston. It will be open to the public from October 22 to 24, and will show the part played by the platinum metals in science and industry today.

Corrosion consultant

Mr. Francis F. Jaray has left Tanks & Linings Ltd., of which he was a founder and technical director, to become a consulting engineer specialising in corrosion proof materials.

Obituary

We announce with regret the death of Mr. Arthur Peake-Jones, advertising manager of the British Tyre & Rubber Co. Ltd., and its subsidiary companies since 1931. He died on August 14, aged 68. He entered the rubber industry in 1913 when he joined the advertising department of B. F. Goodrich Co. Ltd.

Slurry transfer pumps

In the August issue (p. 236) there appeared a photograph of slurry transfer pumps and pipe lines at the catalyst plant of Joseph Crosfield & Sons Ltd. We regret that the caption is misleading. In fact, the slurry transfer pumps were supplied by the Hamworthy Engineering Co. Ltd. Doulton supplied the pipe lines.

EUROPE

Molybdenum restrictions lifted

Restrictions on the use of molybdenum in case-hardening and constructional steels in member countries of the Organisation for European Economic Co-operation have been suspended by a decision of the Council of the Organisation.

These restrictions were imposed in May 1952 as a result of shortages of molybdenum and nickel on world markets. The new decision does not apply to nickel, since the present improvement in supplies is not sufficient to justify the abolition of the restrictions in force.

The Council has instructed the Iron and Steel Committee to follow closely the supply position for molybdenum and to make appropriate proposals for the final repeal of restrictions or for their reimposition should the supply position make it necessary.

GERMANY

Potash works increases output

The potash works at Hattdorf (Kreis Hersfeld), belonging to the Vereinigte Kaliwerke Salzdetfurth A.G., has at present a daily mining output of about 9,000 tons of crude salts, according to its technical director. The plant, which produces potash fertilisers and potassium sulphate, processes about 10,000 tons daily. Its production of pure potash increased from 34,510 tons in 1946 to 198,400 tons in 1952. The works employs 2,200.

NORWAY

Magnetic dressing of iron ores

A new type of magnetic separator for the mining industry has been developed by the firm of Thunes Mekaniske Vaerksted A/S, in conjunction with a leading Norwegian mining concern. Already in operation in various parts of Norway, the new separator is used for dressing and extracting iron ore —using either the wet or the dry system— for the removal of undesired iron from other ores, etc. The permanent magnet system is used and the equipment is independent of electric current. Iron ore concentrate leaves the separator containing over 70% solids and can be sent directly to secondary mills and filters.

Aluminium plant makes headway

Construction of Norway's biggest aluminium plant at Sunndalsöra, West Norway, is ahead of schedule and it is expected that production can start next year. Output will be 40,000 tons p.a. at first, but may be increased to 50,000 tons later. The overall Norwegian production of aluminium is now about 50,000 tons p.a., so that the new plant will almost double the national output.

Production at Sunndalsöra will be in two large halls each about 1,600 ft. long and holding altogether 264 furnaces. The plant is being built with the help of a United States loan, and under the terms of the loan, repayment will be made in the form of aluminium at the rate of about 8,000 tons p.a. The plant is being built by a Government company which already operates an aluminium plant built after the war at Årdal, West Norway.

The Sunndalsöra plant will employ about 1,000 persons when production starts. Many of the workers now helping to build the plant are being given short training courses at Årdal to fit them for permanent employment at the Sunndalsöra plant when it starts production.

A new type of furnace is being installed which will reduce the smoke nuisance, and steps are also being taken to prevent the pollution of the neighbouring Driva River, one of Norway's finest salmon rivers. Sunndalsöra is at the head of a deep fjord, and ships will be able to tie up very close to the factory at a quay about 900 ft. long which is now being built.

Industrial atomic energy

Scientists of 19 countries recently met in Oslo to discuss the problems of atomic power. The main topic discussed was the use of heavy-water reactors. At Kjeller, north of Oslo, Norwegian scientists have built a heavy-water reactor which is now being operated jointly with Dutch scientists. Holland supplied the uranium needed for the Kjeller reactor and Norway the heavy water.

The leader of the Norwegian-Dutch project, Gunnar Randers, said when opening the international conference: 'We know that atomic energy can be utilised also for

non-military purposes and that the world's stock of uranium is bigger than the stock of any other source of energy. It would be strange if one should not soon be able to find a relatively easy method of making use of this power in industry and everyday life . . . At present it appears that the price question is the biggest obstacle . . . If atomic energy is to be given general application, the price of heavy water must be reduced to half its present price.'

Mr. Randers said that the Norwegian-Dutch team had the firm intention to build a new and bigger reactor at Kjeller. The first estimates put the cost at between £1¼ and £1½ million ' and even if we do not have that amount of money, or know when and whether we can obtain it, we are going ahead with the project as though we had the money.'

Mr. Randers wrote an article on Norway's atomic pile in CHEMICAL AND PROCESS ENGINEERING March, 1952.

FINLAND

Paper-mill project

The State-controlled company ' Enzo-Gutzeit ' has decided to build a new paper mill in South-East Finland. The initial annual production of the new factory is estimated at 80,000 tons which is to be increased to 150,000 tons later. The building costs are estimated at 4,500 million marks.

FRANCE

Fatty acids in chemical manufacture

An ever-increasing quantity of fatty acids is being used for industrial purposes other than soap. The reason for this is that modern production methods, such as fractionation and low-temperature solvent crystallisation, permit the manufacture of pure fatty acids with new and constant characteristics. Among the new outlets for fatty acids is the chemical industry. They serve there in the manufacture of aliphatic amides, amines, ketones, quaternary ammonium compounds and other derivatives.

This was stated by Mr. M. K. Schwitzer, author of ' Continuous Processing of Fats ' (published by Leonard Hill Ltd., London, 30s. net), speaking in Paris at the recent 26th Congress of Industrial Chemistry.

ISRAEL

Asbestos plant makes progress

Although the *Isasbest* plant at Nahariya is not yet completed, it has already begun to market asbestos-cement sewage pipe. Construction work began towards the middle of 1952 on behalf of an Israeli industrialist and Swiss asbestos-cement firms. Total investment is $2 million and I£2 million.

The pressure-pipe department is scheduled to go into production in September, while a third section to manufacture corrugated roofing sheet and water and seed container tank sheet is to begin production early in 1954.

NETHERLANDS

Conference on oxidation process

A conference on ' The Unit Process of Oxidation ' is to be held in Holland on May 6 and 7 next. The British Institution of Chemical Engineers and the Chemical Engineering Group of the Society of Chemical Industry are co-operating with the Dutch Koninklijk Institut van Ingenieurs in the organisation of this event.

UNITED STATES

New tallow may cut tinplate costs

Most attempts to find an alternative for palm oil in the tinplate industry have failed. It has now been announced that the Armour Research Foundation, Chicago, have completed their research on modifying tallow to make it similar to palm oil in action. Research details were published by the Bureau of Agricultural and Industrial Chemistry. The new product replaces palm oil pound for pound, yet it is considerably cheaper. It was successfully plant-tested in cold strip rolling.

It is held that the new product, known as RD.1425, might reduce the production costs for tinplate.

New chemical plant on show

The floor space to be occupied by the 24th Exposition of Chemical Industries, which will take place in Philadelphia from November 30 to December 5, is over 40% larger than that occupied by the last display of its kind, which was held in New York over two years ago. Among the exhibits will be an application of the new elastomer *Hypalon* as an impeller in small chemical process pumps designed for handling acids. There will also be a complete line of hard rubber pipe and fittings fabricated from special *Buna N* compounds to handle elevated temperatures up to 225° F., as well as gasoline, oils, carbon bisulphide and other liquids which are solvents of natural rubber compounds.

The advance listing also includes a display demonstrating the rapid advance of titanium and zirconium and their compounds in industry, disclosing new alloys, new zirconium compounds and titanium carbide.

In the exacting field of dry material separations there will be the first showing of a dust-tight gyratory sample sifter for the laboratory. Another display will reveal for the first time a 40 in. suspended centrifugal with fume hood, which incorporates a pneumatic unloader. A new filter, to be shown for the first time, has a tank which can be retracted to expose the filter cartridge for rapid and thorough cleaning.

Mixing equipment will include a mix-muller for solid and semi-solid materials; another exhibit will reveal a newly-designed change-can mixer, featuring a double-planetary stirrer action. At a third, a manufacturer of colloid mills and homogenisers will show a new model variable-speed mill.

For liquid handling there will be a new line of time-saving tube fittings for polythene tubing; the same display will also feature fittings for corrosion-resistant stainless steel and titanium tubing. For handling coal tar and other high melting point materials, there will be a complete line of jacketed pipe and fittings, which includes a new gear-operated jacketed plug cock, an improved relief valve and a newly-designed diaphragm valve, jacketed to maintain working temperature.

For use with liquid heat-transfer agents, there will be a recently developed hot oil heater, applicable to a large number of chemically-reactive processes requiring sustained temperatures up to 600° F. This system is fully automatic, has very high thermal stability, is unaffected by circulation rate and requires no long start-up or shut-down procedures when being placed into or out of operation. Power or mechanical failures will not break down the oil or damage the equipment, it is claimed.

The increasing employment of very low temperature processing has seriously aggravated the corrosion problem, especially with operations requiring the use of giant steel chemical vessels. This is due to the penetrating character of moist vapours, which fill the dead-air spaces under some forms of lining, causing rapid deterioration of the underlying metal. One of the exhibitors at the exposition is offering a solution of this difficulty in the form of a vapour-seal mastic coating having highly adherent properties, which is resistant to acid, alkali and other chemicals, and which, when combined with cork granules, serves as an insulator.

Smaller glycerin production target

A production capacity of 268 million lb. p.a. of glycerin to be reached by January 1, 1955, has been fixed by the Office of Defence Mobilisation. This is a reduction of 10 million lb. from the original goal, but exceeds the capacity of January 1, 1951, by 43 million lb. Of the new total, 128 million lb. will be accounted for by synthetic or fermentation glycerin capacity.

Substitute for glycerin

Production of trimethylol ethane, a new trihydric alcohol, has been started by the Heyden Chemical Corporation. The new alcohol is claimed by the company to have important advantages over glycerin and to permit production of new types of alkyd resins and improvement in existing types of surface coatings, particularly those where glycerin was used.

Propane-fuelled locomotive

The Union Pacific Railroad has developed and made successful tests with a propane gas-operated turbine electric locomotive. It consists of a single unit weighing nearly 276 tons which can deliver upwards of 4,800 h.p.—more than that produced by three diesel units operating together.

Union Pacific plans to place this and similar locomotives in regular freight service between Los Angeles and Salt Lake City.

Anti-corrosion techniques studied

A new system of anti-corrosion maintenance painting for chemical plants, developed by the Pennsylvania Salt Manufacturing Co., was studied recently by 22 European engineers who visited the company under the auspices of the Mutual Security Agency.

Representing nine countries, the visitors discussed the system with Pennsalt corrosion engineers, toured the company's Whitemarsh research laboratories and then examined techniques and results of the programme at the company's Cornwells Heights plant, near Philadelphia, Pa.

Four fundamentals were explained by a company official. These are: (1) Corrosion must be stopped on surfaces before these surfaces are coated or recoated; (2) a minimum of 0.001 in. of primer coat must be applied to the surface; (3) a minimum of three coats of primer and coating must be applied to prevent incidence of pinholes or other flaws in the coating; and (4) a minimum of 0.005 in. total of primer and top coating must be applied to obtain good results in chemical plants or around chemical use points.

How the company codes all plant areas and maintains graphs keeping accurate records of coating performance was explained. The group then discussed various coatings and their suitability under a variety of corrosive conditions. The talk was followed by a discussion of comparative maintenance practices and costs in the countries represented.

New cold rubber ingredient

A new chemical activator which is claimed to reduce the manufacturing costs of GR-S cold synthetic rubber, speed up its production and make a more uniform product has been developed by the Naugatuck Chemicals Division of the U.S. Rubber Co., under the rubber research programme of the Reconstruction Finance Corporation. Widespread use of the new activator, a sulphoxylate derivative, could save the synthetic rubber industry approximately $700,000 annually, it is claimed. Tests, the company says, have shown that it simplifies cold rubber production and improves uniformity of operation as well as uniformity of the rubber. It can be used in formulations for cold latex as well as for solid cold rubber, gives latex better colour and makes it more fluid for easier handling. An initial production of around 600,000 lb. of GR-S with the new activator has been authorised by the Reconstruction Finance Corporation in two government-owned synthetic rubber plants.

Acrylonitrile plant

The B. F. Goodrich Chemical Co. plans to build an $8½ million plant at Calvert City, Kentucky, to manufacture acrylonitrile. The new plant is scheduled to be in operation by the autumn of 1954. It will be the company's second factory at Calvert City—the first one being a recently opened $6-million chloride monomer plant.

The Leonard Hill Technical Group—October

Manufacturing Chemist—Adrenergic Blocking Agents; Emulsions in Cold Wave Lotions; *Oblivon* manufacture; Progress Reports on Fertilisers and Cosmetics and Toilet Preparations; Cost Control in the Chemical Industry.

Muck Shifter—Steam Travelling Jib Cranes; The Case for Oil Firing; Pozzolan Concrete from Fly Ash; Earthmoving Equipment used in the Construction of an American Air Force Base.

Food Manufacture—The Disinfestation of Ships' Holds; Radiation from Fission Materials for the Sterilisation and Preservation of Food.

Paint Manufacture—Rheology of Paint Materials; History of Paints and Varnishes in Great Britain, 2; Automatic Finishing and Testing Electrostatic Spray.

Atomics—Industrial Applications of Radioactive Materials; Radiation Biology; International Conference on Nuclear Physics, Birmingham, 1953; Radioactive Materials and Chemistry Research.

Petroleum—New Platformer Units in American and European Refineries; Instruments and Control Gear for Chemical Plant; New Oil-Drum Finishing Process; Second International Congress on Rheology, 1953; A.C. Installations in New British Tanker; Some Physical Properties of Mineral Oils under High Pressure, 1.

Fibres—Improving the Dyeing Properties of Polyacrylonitrile Fibres; Dyeing of 'Terylene' Polyester Fibre; Fibres for Pulp and Paper Manufacture, Part 3; Detergents in the Wool Textile Industry; Survey of Fibre End Use Developments.

World Crops—Cocoa in the South Pacific; Witches' Broom Disease of Cacao; Fertilisers in Economic Use; The Clove Industry in Zanzibar and Pemba.

Building Digest—Where to Build the Houses of the Future; Planning and Building of Flats Since the War; Small Houses Design and Planning Since the War; Recent Development in Domestic Heating.

Canned lubricating oils

Esso Standard Oil Co. has started to build a $1 million plant for the canning of lubricating oils at Charleston, South Carolina. The new plant is located on property adjoining the company's asphalt refinery and oil terminal. It is estimated that the plant will have annual throughput of 235,000 bbl. of finished products and base stocks for automotive and industrial oils.

First private nitrogen plant since the war

The first privately-financed post-war nitrogen plant in the United States is now in operation at Sterlington, Louisiana.

Belonging to the Commercial Solvents Co., the new plant facilities will double the firm's output of nitrogen for agricultural and industrial use. In addition, the new units for nitrogen solutions and crystalline ammonium nitrate fertilisers are also operating.

Output from these units is already committed for the coming year, emphasising the continuing world-wide shortage of nitrogen.

Japanese firm to make American ore-dressing machinery

The Western Machinery Co. of San Francisco announces the licensing of the Sumitomo Machinery Co. of Tokyo and Osaka to manufacture ore dressing machinery. An agreement limits the licence to manufacture and sale in Japan with the Western Machinery Co. reserving other Far Eastern areas for itself.

Japan is chiefly interested in the *Wenco* mobile mill, a prefabricated semi-portable processing unit capable of upgrading a variety of metallic and non-metallic minerals by the media separation process. The Japanese will use it chiefly to upgrade coal in the development of domestic low-grade coal resources.

Iron powder made by new process

Republic Steel Corporation has perfected a process for making powdered iron which is largely automatic and continuous in operation. Republic will build a new plant at Toledo, Ohio, to produce the powder on a commercial scale. Construction is scheduled to start soon and the new plant, with an initial capacity of 50,000 lb. daily, is expected to be completed next summer. Iron powder is used by about 100 companies in the United States to form gears and other precision mechanical parts.

New protective coating

The B.F. Goodrich Co. has developed a new quick-drying material that can be sprayed like paint on metal to make the treated surface capable of withstanding temperatures as high as 5,000° F. The material, called *Pyrolock*, was developed initially for use in the rocket and guided missile field.

Allied Chemical's new acid plant

The General Chemical Division of the Allied Chemical & Dye Corporation plans to build a large sulphuric-acid plant at Painesville, Ohio. This marks the second major expansion project in the development of the company's nation-wide sulphuric-acid production facilities. Construction of another acid plant at Baton Rouge was started early in May.

New plastic sheet process

A low-cost, continuous-output process for light, strong and rigid sheets of plastic material has been announced by the Campco Division of the Chicago Molded Products Corporation. In many applications, the product will compete with steel, aluminium, wood, glass, rigid vinyl, acetate, fibreboard, rubber and some textiles as well as with moulded plastics, according to a Campco official. He said the sheet was made by forcing a plastic 'alloy' of polystyrene and rubber through a heated die. Sheets of any length could be turned out and colour possibilities were unlimited.

It was claimed that wooden dies costing less than $100 could be used, as against metal dies costing many thousands of dollars for injection mouldings.

Sulphur from ores

The American Sulphur & Refining Co., which was initially formed to develop a process for the extraction of elemental sulphur from native sulphur-bearing ores, is now building its first commercial plant near Fillmore, California. The plant, it is claimed, will produce about 100 tons/day of sulphur of 99.5% purity, from ores with a sulphur content of 20%. This cost is stated to be competitive with that of Frasch sulphur.

New leather-tanning extract

Leather shoe soles tanned with an extract made from canaigre, a wild plant which grows in the south-western United States, wear as well as leather soles tanned with imported material, a chemist of the U.S. Bureau of Agricultural and Industrial Chemistry has reported to the annual meeting of the American Leather Chemists' Association in Cincinnati. About 85% of the vegetable tannin now used in the U.S. is imported. A pilot plant has been established at the Philadelphia laboratory where chemical engineers will study the large-scale manufacture and cost of making high-grade canaigre extract.

NEW ZEALAND

Kraft pulp production

Commercial production of kraft pulp for export has now started at the pulp section of the £6.6 million paper-making plant at Kinleith near Tokoroa, owned by New Zealand Forest Products Ltd. Output is planned to total 45,000 tons p.a.

At present all the pulp is being made into kraft sheets, but eventually a lot of it will be diverted to a nearby building where a 262-ft. long paper-making machine is being assembled. This part of the factory is expected to be ready in October; it will produce strong brown paper.

AUSTRALIA

New uranium find

The Commonwealth Government's aerial detection services, using specially equipped aircraft, have discovered a uranium field which is described officially as having surface indications equal to, if no better than, the early Rum Jungle indications.

Rum Jungle is at present the biggest uranium field in Australia. The London *Times* reports that the new find, which is 230 miles from Darwin in a remote area, will be the first uranium discovery to be tested thoroughly since the opening up of Rum Jungle. It will be some months before extensive drilling and other tests can determine exactly the extent of the field, which is 80 miles east of the tiny Northern Territory township of Pine Creek and 30 miles from the nearest track. The discovery has been inspected by the United States consultant geologist, Dr. J. K. Gustafson, who is a member of the advisory committee on raw materials to the United States Atomic Energy Commission.

CANADA

New plant produces paint ingredients

The first commercial shipment of Canadian-made pentaerythritol in tonnage quantity has been made from the Varennes, Quebec, plant of St. Maurice Chemicals Ltd. This firm is jointly owned by Heyden Chemical Corporation and Shawinigan Chemicals Ltd. The plant has an annual capacity of 30 million lb. of formaldehyde and 3 million lb. of pentaerythritol, the base for weather-resistant, fast-drying paints, varnishes, lacquers and other surface coatings.

BRAZIL

Fertiliser factory ordered

The President of Brazil has authorised the advance of 87.4 million cruzeiros to the National Petroleum Council for the construction of a nitrogen fertiliser factory. The factory will be built near the Cubatao Petroleum Factory, outside Santos, and will produce ammonia, nitric acid, nitrate of ammonia and fertiliser.

The equipment for the factory has been purchased in Germany and it is hoped that 80% of all equipment needed will have arrived at the Port of Santos by the end of this year.

The recovery of sulphur from the residual gases of the Cubatao Refinery is also being studied.

COLOMBIA

Natural gas plant

The Colombian Petroleum Co., subsidiary of an American company, has announced that it plans to build a $5 million plant at Petrolea, Colombia, for the collection and distribution of natural gas coming from its Barco concession in the Department of Norte de Santander, Colombia.

The plant will be capable of a daily production of 61 million cu. ft. of natural gas from which it will obtain 61,000 gal. of gasoline.

ITALY

Montecatini to make 'Terylene'

The Italian chemical company Montecatini, of Milan, are to manufacture and sell *Terylene* polyester fibre in Italy under licence from I.C.I.

As already announced, I.C.I. have decided to spend nearly £20 million on the *Terylene* plant which is now being built at Wilton, North Yorkshire (see CHEMICAL & PROCESS ENGINEERING, August 1953). World demand for the new fibre is expected to exceed the capacity of the British plant, which, when completed, will have a total output of 22 million lb. p.a.

PHILIPPINES

New fertiliser plant

A fertiliser plant owned by the Philippine government and constructed in conjunction with the Maria Cristina hydro-electric system in Lanao, is now operating at full capacity. It is able to cover about half the country's fertiliser requirements. The cost of the plant was 12 million pesos.

PAKISTAN

Government help for oil companies

Pakistan Petroleum Ltd. started their first test well at Zin, Baluchistan, recently. The Governor-General, who performed the formal spudding-in ceremony, assured the companies of the assistance of the Pakistan government, which had recently decided to subscribe 30% of the capital of Pakistan Oilfields Ltd. and Pakistan Petroleum.

He also said that the government were actively interested in the natural gas discovered by Pakistan Petroleum at Sui, Baluchistan.

Glass factory planned

A new industrial concern with a capital of 5 million rupees has been established in Karachi to make window and plate glasses. The company, Pakistan Glass Sheets and Wares Manufacturers Ltd., has secured a plot of land in the Sind Industrial Trading Estate. Permission for installing the factory and for the capital issue has been granted by the Pakistan government.

Sugar mills for Punjab

A new programme of industrial development in the Punjab includes the construction of two sugar mills at Leiah and Lyallpur, each with a daily crushing capacity of 1,000 tons of sugar cane and an annual production of 15,000 tons. The programme also includes the construction of a new rayon mill at Okara.

Chemical research laboratories

The Planning Committee of the Council of Scientific and Industrial Research has recommended the setting up of a Central Laboratory in Karachi and two Regional Laboratories in Lahore and Dacca. The committee also recommended that a Research Section be established in Peshawar in association with the university to cater for the social needs of the N.W.F.P.

The committee opined that the Central Laboratory should have a physical research and testing section, chemical research section, biochemical research section, drugs and pharmaceuticals research section, building materials research section, fuel research section and plastics research section (including paints and varnishes); the Regional Laboratory in Lahore should comprise a metallurgical research section (including ore dressing and testing of minerals), industrial fermentation research section, oils and fats research section, glass and ceramics research section and food technology research section; the Regional Laboratory in Dacca should comprise the leather research section (principally providing facilities for investigations in tanning material resources of the region), fuel research section (principally for work on peat-lignite coal deposits of the area), food and fruit technology and plant and animal products research section (covering work on minor forest products and biological, agricultural and industrial estates).

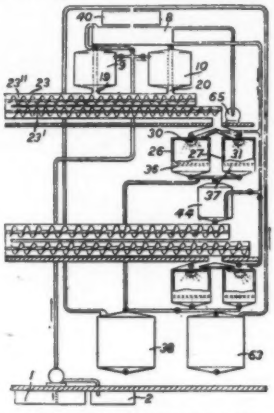
Chemical Engineering Invention

MONTHLY SUMMARY OF PATENT CLAIMS

Separating fatty acids

Stearine is separated from mixtures of fatty acids containing oleine and unsaponifiable materials by dissolving the warmed mixture in liquid hydrocarbons, cooling the solution to a temperature between 0 to 10°C., and separating off the stearine formed by vacuum filtering. The original mixture is warmed to about 50°C. The solvent may be removed from the stearine and liquid portions by evaporation. The stearine may be purified by washing it with the hydrocarbon, followed by separation and drying as before.

The solvent from a storage tank 2 is pumped to a solvent supply tank 8. The warmed fatty acid mixture is pumped from a storage tank 1 to a mixing vessel



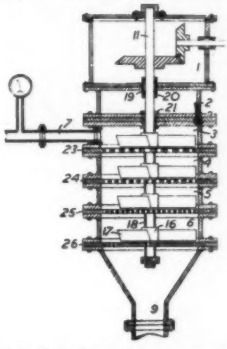
9 or 10. Solvent is fed to this from tank 8, preferably in equivalent proportions. The solution is then released through valve-controlled outlets 19 or 20 into an endless carrier-cooler apparatus 23, composed of two parallel sections 23^{I} and 23^{II}. Here the solution is cooled to a temperature between 0 to 10°C., the stearine crystallising out. From the cooler the mixture is fed to a vacuum filter tank 26 or 27 equipped with heater filters 36, 37. The filtrate containing oleine and unsaponifiable materials is drawn off to a collecting tank 38 where the solvent is evaporated, led to a cooler 40 and returned to the solvent supply tank 8. The stearine on the filter plates of the filters 26 or 27 is washed with fresh solvent supplied to spray pipes 30 or 31, arranged in the top of each filter tank and connected to tank 8. The filtrate is again drawn off to the collecting tank 38, and the solid stearine on the filter plates heated and the molten mass drawn off to a collecting tank 44, to be dried by evaporation.

The whole of the above plant may now be duplicated, solvent supplied to the stearine in tank 44 and the resulting solution re-treated as above. The doubly separated and purified stearine is finally collected in a receiver 63. Vacuum is maintained throughout the system by a pump 65 connected to the solvent supply tank 8.—650,720, *G. Neudert and T. A. Lange.*

Preparation of viscose

In the preparation of viscose a mixture of cellulose xanthate and aqueous caustic soda is fed through a granulator having a number of compartments each provided with a perforated base and rotating blades. The mixture is continuously fed to the top of the granulator and continuously withdrawn from the bottom. The rate of feed and the speed of rotation of the blades is such that the mixture offers substantially no resistance to the rotation of the blades of the granulator.

As shown, the granulator consists of a cylindrical shell divided into four compartments 3, 4, 5, 6 by perforated bases 23, 24, 25, 26. The perforations in the bases successively decrease in size. Compartment 3 is provided with an inlet pipe 7 carrying a pressure gauge. An outlet pipe



9 is provided below compartment 6. A power-driven shaft 11 extends throughout the granulator and is driven by gearing in chamber 1. In each chamber 3, 4, 5, 6 the shaft bears a collar 16 carrying three rectangular radial blades 17, each tilted slightly away from the vertical, and the collars are so fixed that there is a minimum distance between the blades and the perforated bases. The exposed part of the shaft is protected in each chamber by a shield 18. Chambers 1 and 2 are closed, except for the bearing 19 in which the shaft rotates and a gland 21 in the base of chamber 2. This chamber 2 acts as a safety trap, preventing oil from the oil seal 20 around the bearing 19 from contaminating the mixture in chamber 3, and also preventing contamination of the gearing by the xanthate-caustic soda mixture should the pressure within the granulator build up and force the mixture through the gland 21. The cellulose xanthate and caustic soda may be premixed before being fed to the granulator.—642,270, *Courtaulds Ltd., W. R. Weigham, W. J. C. Field and F. G. Dunton.*

Phosphate glasses for water softening

Phosphate glasses for domestic water softening, produced for example by heating dihydrogen mono-sodium orthophosphate and chilling to form a glass, having an alkali metal oxide to phosphorus pentoxide ratio of at least 9 to 10, are rendered more easily soluble in water by the following method: by forming as a coating on the surface of the finely-ground glass particles, the acid reversion product, *viz.* dihydrogen

FIG. 1.

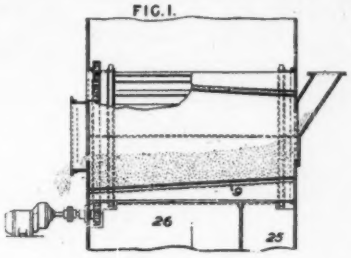
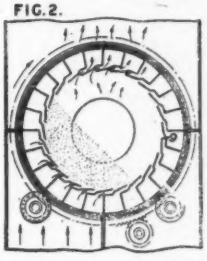


FIG. 2.



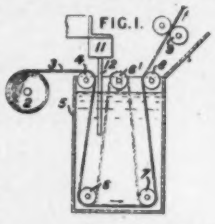
disodium pyrophosphate, and by humidifying and heating, and incorporating in the coating, or mixing with the coated particles a salt which in water will react with the acid reversion product to generate a gas, thereby dissociating the particles and speeding solution. Such salts are sodium carbonate, bicarbonate, sulphite or bisulphite.

In a preferred embodiment the glass particles, ground to pass an 80-mesh sieve, mixed with about 5 parts of sodium carbonate and 5 of sodium bicarbonate, per 100 parts of phosphate, are fed into a rotating drum, the inner surface of which forms a frustrum of a cone. The walls are formed by a series of louvres 9 (Fig. 2), through which at the inlet end of the drum through flue 25 air at a temperature of about 60°C., with a humidity of 90%, hydrates and renders sticky the surface of the phosphate particles. These particles then pass to a drying zone, where air at a temperature of 150°C. enters *via* flue 26. The added moisture is thereby partially removed and the remaining moisture reacted with the glass to form the acid reversion product as a coating, which also contains the adhering sodium carbonate and bicarbonate, on the surface of the particles. Alternatively, the surface hydra-

tion may be effected by means of a hydrated salt or a 10% solution of water in acetone, followed by heating to effect reversion. Specification 642,945 is referred to.—642,944, *Albright & Wilson Ltd.*

Ultrasonics in cellulose production

In the production of alkali cellulose, cellulosic material in contact with alkali solution is subjected to high-frequency sound or ultra-sound wave radiations. The frequency of the waves may be from about 1,000 to 1 million or more c/s. and the waves may be generated by means such as a piezo-electric sound generator, a magnetostriction sound generator or an electromagnetic sound generator. The cellulosic material to be treated may be in sheet form, as a continuous web, or in disintegrated form.



As shown in Fig. 1, a sheet of cellulosic fibres 3 from a supply roll 2 is led at a controlled rate through an aqueous sodium hydroxide solution in a vessel 5. A transmission tube 12 of a sound generator 11 extends into the solution which is subjected to high-frequency sound wave radiations. The sheet of fibres is passed round guide rolls 4, 6, 7 and 8, or alternatively 4, 6, 6¹, 7 and 8 if longer contact between the sheet and the solution is required, and is then pressed between rollers 9 to remove excess alkali solution, after which it may be either disintegrated and aged, or subjected again to the sound wave radiations. In modifications, the web is treated with alkali and subjected to the wave radiations after it leaves the alkali bath or, alternatively, cellulose fibres of varying forms are conveyed through the irradiated alkali solution on a continuous belt.—641,609, *American Viscose Corporation.*

MEETINGS

Institution of Chemical Engineers

October 17. ' Some Aspects of Chemical Engineering in the Manufacture of Man-made Fibres,' by W. G. Daroux, 3 p.m., The University, Birmingham.

November 3. 'Agitation in Process Design,' by S. J. Green, 5.30 p.m., Geological Society, Burlington House, Piccadilly, London, W.1.

Institute of Welding

October 8. 'Automatic Welding,' by R. L. Swan, 7 p.m., Mansion House, Portland Place, London, W.1.

Society for Applied Bacteriology

October 20. ' Microbial Spoilage in Industrial Materials,' by Dr. T. Richards, L. D. Galloway, J. G. Savory, E. Howard and Dr. R. Burgess, 3 p.m., Lecture Hall, Royal Society of Tropical Medicine and Hygiene, Manson House, 26 Portland Place, London, W.1.

Chemical Society

October 13. ' Recent Research on Tin and its Compounds,' by Dr. E. S. Hedges, 7.15 p.m., Agriculture Theatre, Queen's University, Belfast. Joint meeting with the S.C.I.

October 13. ' Manufacture of Sulphuric Acid from Anhydrite,' by Dr. J. S. Dunn, 7 p.m., Municipal College, Anglesea Road, Portsmouth.

October 15. ' The Mechanism of Reactions between Gases and Solids,' by Dr. J. S. Anderson, 7.30 p.m., Lecture Theatre, The Royal Institution, Albemarle Street, London, W.1.

October 15. ' Synthesis of Simple Peptides,' by Prof. F. E. King, 7 p.m., Department of Chemistry, The University, Bristol. Joint meeting with the R.I.C. and the S.C.I.

October 16. ' Chemistry at St. Andrews: a Historical Survey,' by Prof. J. Read, 5.15 p.m., Chemistry Department, United College, St. Andrews.

October 22. ' Reaction Mechanism and Molecular Geometry,' by Prof. C. W. Shoppee, 5 p.m., Chemistry Lecture Theatre, The University, Liverpool. Joint meeting with the R.I.C., S.C.I., British Association of Chemists, and the University Chemical Society.

October 23. ' Structure, Stereochemistry and Inclusion Compounds of some Phenol Derivatives,' by Prof. W. Baker, 7.30 p.m., Robert Gordon's Technical College, Aberdeen. Joint meeting with the R.I.C. and the S.C.I.

October 23. 'Analytical Errors: Heinous and Otherwise,' by Dr. T. B. Smith, 4.30 p.m., Chemistry Department, The University, Birmingham.

October 23. ' Fluorescence of Solutions,' by Dr. E. J. Bowen, 3.30 p.m., The Royal Technical College, Glasgow.

October 26. ' Methods of Measuring Reaction Velocities in Solution,' by R. P. Bell, 5.30 p.m., Chemistry Department, University College of Cardiff.

October 29. ' The Comparative Chemistry of Carbon and Silicon,' by Prof. E. D. Hughes, 7.45 p.m., Chemistry Lecture Theatre, Queen's University, Belfast.

October 29. 'Allene Chemistry,' by Prof. E. R. H. Jones, 4.45 p.m., The University, Nottingham.

October 30. ' The Polymerisation of Sulphur,' by Prof. G. Gee, 8.30 p.m., Chemical Laboratory, The University, Cambridge.

November 2. ' Some Problems Raised by the Visualisation of Big Molecules,' by Dr. R. W. G. Wyckoff, 5 p.m., University College, Leicester.

November 3. ' Pernitrous Acid and its Nitrating and Hyroxylating Properties,' by R. Heslop, 6.30 p.m., Chemistry Lecture Theatre, The University, Leeds.

November 6. ' Present Trends in Surge Tank Design,' by Dr. C. Jaeger, 5.30 p.m., Storey's Gate, St. James's Park, London, S.W.1.

November 6. ' The Bacteriostatic Properties of Heterocyclic Compounds,' by Prof. A. Albert, 5 p.m., Chemistry Department, The University, Southampton.

Society of Chemical Industry

Chemical Engineering Group

October 10. George E. Davis Memorial Lecture, by Norman Swindin, 3 p.m., College of Technology, Manchester.

Plastics and Polymer Group

October 13. 'Adiabatic Compression and Expansions of Polystyrene,' by S. D. Eagleton; ' Energy Conversion in the Flow of High Polymers and Application to Injection Moulding,' by H. L. Toor, 6.30 p.m., Chemical Society Rooms, Burlington House, Piccadilly, London, W.1.

CHEMICAL & PROCESS ENGINEERING

ENQUIRY BUREAU

Stratford House, 9 Eden Street, London, N.W.1

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